Draft
Comprehensive Risk Assessment Methodology

September 2000

DRAFT
COMPREHENSIVE RISK ASSESSMENT METHODOLOGY

2

3

LIST OF TABLES

LIST OF FIGURES

4

ACRONYMS

AF	absorption factor
AL	action level
AME	Actinide Migration Evaluation
ANOVA	Analysis of variance
AOC	Area of Concern
AUF	area use factor
BAF	bioaccumulation factor
BD	building debris
BZ	Buffer Zone
BZSAP	Buffer Zone Sampling and Analysis Plan
CAD/ROD	Corrective Action Decision/Record of Decision
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
cm^2	square centimeter
cm/hr	centimeter per hour
CMS	Corrective Measures Study
COC	chemical of concern
CRA	Comprehensive Risk Assessment
CRAVE	Carcinogenic Risk Assessment Verification Endeavor
CRQL	contract-required quantitation limit
CSF	cancer slope factors
CSM	Conceptual Site Model
CWQS	Colorado State Water Quality Standard
DBP	di-n-butyl phthalate
DCF	dose conversion factor
DOE	U S Department of Energy
DQF	Data Quality Filter
DQO	data quality objective
ECOC	ecological chemical of concern
EcoSSL	ecological soil screening levels
EG&G	EG&G Rocky Flats, Inc
Eh	reduction-oxidation potential
EPA	U S Environmental Protection Agency
EPC	Exposure Point Concentrations
ERA	Ecological Risk Assessment
ERAM	Ecological Risk Assessment Methodology
EU	exposure unit
FS	Feasibility Study
ft^2	square feet
FY	fiscal year
GIS	Geographic Information System
HEAST	Health Effects Assessment Summary Tables
HEC6-T	sedimentation instream networks
HHRA	Human Health Risk Assessment

5

ACRONYMS, cont.

HI	hazard index
HQ	hazard quotient
IA	Industrial Area
IA Strategy	Industrial Area Characterization and Remediation Strategy
IAEA	International Atomic Energy Agency
IASAP	Industrial Area Sampling and Analysis Plan
ICRP	International Commission on Radiological Protection
IHSS	Individual Hazardous Substance Site
IM/IRA	interim measure/interim remedial action
IMP	Integrated Monitoring Plan
IR	ingestion rate
IRIS	Integrated Risk Information System
kg	kilogram
kg/mg	kilogram per milligram
K-H	Kaiser-Hill, LLC
km	kilometer
L/1,000 cm^3	1 liter per 1,000 cubic centimeters
L/day	liters per day
LHSU	lower hydrostratigraphic unit
LOAEL	lowest observed adverse effect level
µm	micron
µg/m^3	micrograms per cubic meter
µg/kg	micrograms per kilogram
m	meter
m^2	square meter
m^3/day	cubic meters per day
MDL	method detection limit
mg/cm^2	milligrams per square centimeter
mg	milligram
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mg/m^3	milligrams per cubic meter
mg/vol	milligrams per volume
mrem	millirem
mrem/pCi	millirems per picocurie
mrem/pCi/g	millirems per picocurie per gram
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NCRP	National Council on Radiation Protection and Measurement
NFA	no further action
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
ORNL	Oak Ridge National Laboratory
OU	Operable Unit

ACRONYMS, cont.

PAC	Potential Area of Concern
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi	picocuries
pCi/g	picocuries per gram
pCi/L	picocuries per liter
PCOC	potential chemical of concern
PEC	probable effects level
pH	hydrogen ion activity
PMJM	Preble's meadow jumping mouse
PPRG	programmatic preliminary remediation goals
PQL	practical quantitation limit
PRG	preliminary remediation goals
QA	quality assurance
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation and Recovery Act
RfC	Reference Concentration
RFCA	Rocky Flats Cleanup Agreement
RfD	reference dose
RFETS	Rocky Flats Environmental Technology Site
RFI/RI	RCRA Facility Investigation/Remedial Investigation
RI	Remedial Investigation
RIVM	Rijksinstituut Voor Volksgezondheid En Milieu
RMA	Rocky Mountain Arsenal
RME	reasonable maximum exposure
SAP	sampling and analysis plan
SCM	Sitewide Conceptual Model
SCMTM	Sitewide Conceptual Model Technical Memorandum
Site	Rocky Flats Environmental Technology Site
SLERA	screening level ecological risk assessment
SMDP	scientific management decision point
SOP	standard operating procedure
SQG	sediment quality guideline
SSV	soil screening value
SVOC	semivolatile organic compound
SWD	soil/water database
TEC	threshold effects level
TM	Technical Memorandum
TRV	toxicity reference value
TSS	total suspended solids
UBC	Under Building Contamination
UCL	upper confidence limit
UHSU	upper hydrostatigraphic unit
UTL	upper tolerance limit
VOC	volatile organic compound

7

ACRONYMS, cont.

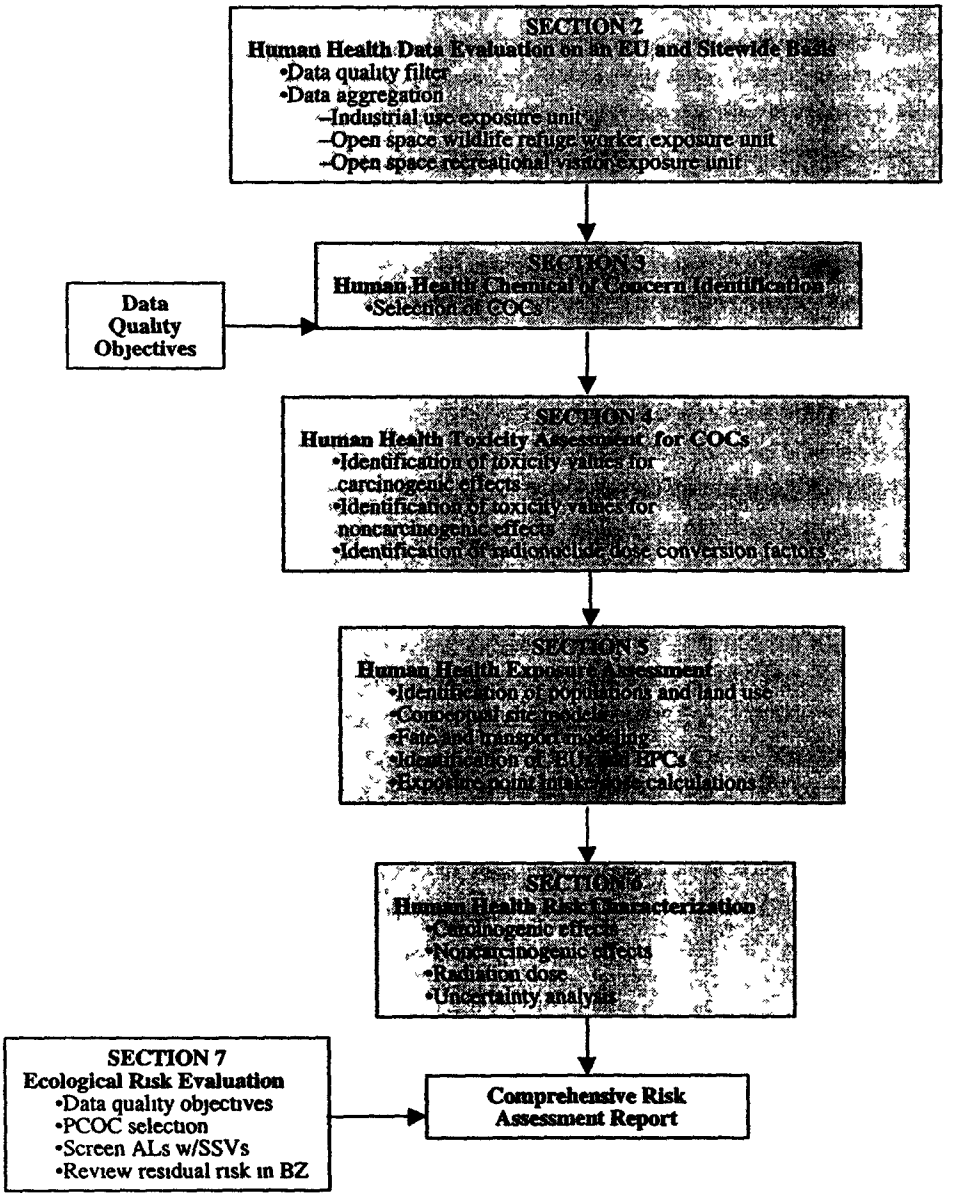
vol/day	volume per day
WEPP	Watershed Erosion Prediction Project
WS	White Space

8

1.0 INTRODUCTION

The human health and ecological risks from chemicals, metals, and radionuclides remaining at the Rocky Flats Environmental Technology Site (RFETS) (the Site) after remediation activities must be assessed to ensure that the post-remediation state is protective of human health and the ecosystem Human health and ecological risks will be assessed in the Comprehensive Risk Assessment (CRA) for RFETS This document outlines the CRA Methodology to be used to calculate human health and ecological risks at RFETS (Figure 1-1)

Figure 1-1
CRA Process



9

Data will be collected from all areas of RFETS to support the data needs of the CRA The data collected will assess the nature and extent of contaminants in surface soil, subsurface soil, building debris, groundwater, surface water, and sediments, to ensure that human health and ecological risks from post-closure uses are protective

Human health risks for the CRA will be calculated based on the post-closure land uses at RFETS These land uses are industrial, recreational open space, wildlife refuge open space, and offsite residential The onsite industrial, recreational and wildlife refuge land uses, as well as an offsite residential land use, will be evaluated on a Sitewide basis Risk will initially be evaluated based on the exposure units (EUs) applicable to the future land uses at RFETS Data will be aggregated across EUs to compare with the Rocky Flats Cleanup Agreement (RFCA) surface soil action levels (ALs), and also aggregated across each type of environmental media and building material to develop human health risks associated with Sitewide and EU-specific COCs

Ecological risks for the CRA will be evaluated using a direct comparison of risk-based action levels against Site data Media-specific action levels will be expressed as concentrations that can be directly compared to the Site environmental data. The criteria for this screen will be developed for various types of receptors (omnivorous mammals, piscivorous birds, etc) and will represent ecotoxicologically 'safe' exposures for each of the potential chemicals of concern (PCOCs) for each receptor group This approach is similar to development of Preliminary Remediation Goals (PRGs) for human health risk assessments (EPA 1989), and allows more efficient evaluation of environmental data for possible risk to toxic exposures. The Site environmental data for the ecological risk evaluation will be collected according to the Industrial Area (IA) Sampling and Analysis Plan (IASAP) (DOE 2000) Site data can be aggregated across an IHSS, a remediation/excavation area, or compared on a point-to-point basis to the media-specific action levels

The nature and extent of contaminants in Individual Hazardous Substance Sites (IHSSs), Potential Areas of Concern (PACs), Under Building Contamination (UBC) Sites, Building Debris (BD) Sites, and White Space (WS) Areas (areas with no known contamination), will be assessed to support the CRA The nature and extent of contaminants in IHSSs, PACs, and UBC Sites, and WS Areas in the IA will be determined according to the IASAP The nature and extent of COCs in IHSSs, PACs, and WS Areas in the Buffer Zone (BZ) will be determined according to the BZ Sampling and Analysis Plan (BZSAP) (to be completed in FY2001) The nature and extent of COCs in BD sites will be determined using the building-specific Pre-Demolition Survey Reports

This report is organized to describe the human health and ecological aspects of the CRA Methodology Human Health specific methods are described first in Sections 2.0 through 6 0 Ecological risk assessment methods are described in Section 7 0 The CRA Report Organization is described in Section 8 0

10

2.0 DATA EVALUATION PERFORMED ON AN EXPOSURE UNIT AND SITEWIDE BASIS FOR HUMAN HEALTH RISK PURPOSES

Data evaluation and aggregation will be performed on an exposure unit and sitewide basis for the Human Health Risk Assessment (HHRA) Methods are described below The data quality objective (DQO) process specifies project decisions and techniques necessary to generate quality data and make associated conclusions Each step of the process is described below

2.1 DATA QUALITY OBJECTIVES

The DQO process is a series of planning steps based on the scientific method designed to ensure that the type, quantity, and quality of environmental data used in decisionmaking are appropriate for the intended purpose The EPA has issued guidelines to help data users develop site- and project-specific DQOs (EPA 1994a) The DQO process is intended to.

- Clarify the study objective,
- Define the most appropriate type of data to collect,
- Determine the most appropriate conditions under which to collect the data, and
- Specify acceptable levels of decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the design

The DQO process specifies project decisions, the data quality required to support those decisions, specific data types needed, data collection requirements, and analytical techniques necessary to generate the specified data quality The DQO process consists of seven steps Each step influences choices that will be made later in the process These steps are as follows

- Step 1 State the problem,
- Step 2 Identify the decision,
- Step 3 Identify the inputs to the decision,
- Step 4 Define the study boundaries,
- Step 5 Develop a decision rule,
- Step 6 Specify tolerable limits on decision errors, and
- Step 7 Optimize the design

During the first six steps of the DQO process, the planning team develops decision performance criteria (i e , DQOs) for the data collection design All decision rules need to be

considered, as appropriate The final step of the process involves developing the data collection design based on the DQOs

2.1.1 DQO Step 1: State the Problem

The human health risks from contaminants in environmental media and building material at RFETS need to be quantified to determine whether the final remedy at RFETS is protective of human health In order to quantify risks, the nature and extent of COCs must be adequately assessed to characterize human health risks at RFETS and the methodology by which human health risks are calculated must be developed

The problem is "The human health risks from environmental media and building material must be quantified in a technically sound and defensible manner "

2.1.2 DQO Step 2: Identify the Decision

The CRA questions that need to be resolved are listed below

1 Have the nature and extent of chemicals, metals, and radionuclides within IHSSs, PACs, UBC Sites, BD Sites, and WS Areas been identified with adequate confidence, based on site history (process knowledge) and analytical data?

2 Has a methodology been developed to adequately assess human health risks to support Site regulatory closure?

3 Are long-term risks to human receptors in an EU acceptable, based on probable post-closure uses?

4 Are long-term risks to onsite and offsite receptors via the air and surface water pathways acceptable, based on post-closure uses?

2.1.3 DQO Step 3: Identify the Inputs to the Decision

The information needed to resolve the CRA decision statements described above is listed below

1 Characterization data from Remedial Investigation (RI Reports), Resource Conservation and Recovery Act (RCRA) Facility Investigation(RFI)/RI Reports, Feasibility Studies (FSs)/Corrective Measure Studies (CMSs), Remedial Action Reports, Integrated Monitoring Plan (IMP) Reports, Pre-Demolition Survey Reports, and other projects and data sets, including IASAP-generated, historical, and IMP data (e g , concentrations of contaminants in surface and subsurface soil, surface water, groundwater, air, and biota), will be used as inputs to the CRA

2 All available historical information, sampling data, and risk assessment requirements will be used to determine adequate sampling locations and densities for IHSSs, PACs, UBC Sites, BD Sites, and WS Areas to support CRA decisions

3 All chemical, metal, and radionuclide data will meet requirements set forth in the Guidance for the Data Usability in Risk Assessment (EPA 1992a).

12

4 All chemical, metal, and radionuclide data to be used in the CRA will be screened through the Data Quality Filter (DQF) (DOE 2000) for each type of environmental media and building material as prescribed in this CRA Methodology document All available data will be screened

5 All data used in the CRA will also be screened through the COC selection process as prescribed in this CRA Methodology for each type of environmental media and building material separately All data that passes the DQF will be screened

6 All data used in the CRA will also be screened using professional judgement to ensure the data meet risk assessment needs as prescribed in this CRA Methodology The screening will be performed according to environmental media and building material All COC data will be screened

7 All data that passes steps 4,5, and 6 will be used to calculate the human health risks as prescribed in this CRA Methodology Human health risks from all COC data will be calculated

2.1.4 DQO Step 4: Define the Study Boundaries

Decision boundaries are used to determine when and where data will be collected These decision boundaries are listed below

1 The data associated with IHSSs, PACs, UBC Sites, BD Sites and WS Areas will be aggregated into EUs as designated in Section 2.4 below. EU assessments are applicable to surface soil only

2 EU sizes and methods for development are documented in Section 2 4 The size of an EU is based on the potential land uses and receptors (Figure 1 of Attachment 5 to RFCA [DOE 1996a]) An additional EU is being developed for an onsite wildlife refuge worker An EU is not defined for an offsite resident

3 AL comparisons will be performed on aggregated data for the COCs contained in an EU to account for direct exposure, including contact with multiple contaminants

4 The data associated with IHSSs, PACs, UBC Sites, BD Sites, and WS Areas will be incorporated into Sitewide analyses for the air and surface water pathways as designated in the CRA Methodology Sitewide analyses are applicable to surface soil, subsurface soil, building debris, groundwater, surface water, and sediments

5 The spatial extent of the Sitewide assessment will consist of all available sample results for each environmental media and building material Sitewide

6 The CRA modeling effort will include the assessment of the air and surface water pathways on a Sitewide basis The contaminant load to surface water includes COC transport from surface soil, unsaturated and saturated zone soil, BD, and sediments The modeling effort will support the derivation of exposure point concentrations (EPCs) for land uses identified in Figure 1 of Attachment 5 to RFCA (DOE 1996a), as well as an onsite wildlife refuge worker, and an offsite resident

7 Soil from 0 to 6 inches will be assessed as surface soil. Soil from 6 inches to the top of the saturated zone or top of bedrock, as appropriate, will be assessed as subsurface soil.

13

8 Temporal constraints for environmental media will be based on the timeline for historical sampling and analysis activities Also, temporal analyses will be applicable to the magnitude of groundwater and surface water sampling results over time

2.1.5 DQO Step 5: Develop a Decision Rule

The decision rules for the data evaluation are listed below

1 If the nature and extent of chemicals, metals, and radionuclides are known for an EU with sufficient certainty, so that human health risks and doses can be adequately quantified, then additional sampling and analysis will not be performed Otherwise, additional sampling and analysis will be performed

2 If human health risks and doses are acceptable for RFETS, then a No Further Remedial Action Corrective Action Decision/Record of Decision (CAD/ROD) will be developed Otherwise, further evaluation, management, or remediation will be required

3 The following criteria will be used to determine whether the human health risks and doses are acceptable

   a) Are human health carcinogenic risks for direct contact by a receptor with chemicals, metals, and radionuclides (as determined by the AL screen) in soil in an EU and from air and surface water pathways due to contact, ingestion, or inhalation, as determined by a forward risk assessment, greater than 10^{-4} for the appropriate land use? If yes, then evaluation, management, or remediation is necessary If no, then no further remedial action is necessary

   b) Do human health noncarcinogenic risks for a receptor from chemicals and metals (as determined by the AL screen) in soil in an EU and air and surface water pathways due to contact, ingestion, or inhalation, as determined by a forward risk assessment, have a hazard index (HI) greater than 1 for the appropriate land use (e g , open space visitor, office worker, or wildlife refuge worker land use)? If yes, then evaluation, management, or remediation is necessary If no, then no further remedial action is necessary

   c) Is radiation dose to an individual from direct contact with radionuclides (as determined by the AL screen) in soil in an EU and air and surface water pathways due to contact, ingestion, inhalation, or external irradiation, as determined by a forward risk assessment, greater than the acceptable annual radiation dose limit of 15 millirems (mrem) for an open space visitor, office worker, or wildlife refuge worker land use, or 85 mrem for a hypothetical future resident, whichever is lower? If yes, then evaluation, management, or remediation is necessary If no, then no further remedial action is necessary

   d) Is radiation dose to an individual from radionuclides in air and surface water due to contact, ingestion, or inhalation, as determined by a forward risk assessment, greater than the acceptable annual radiation dose limit of 15 mrem for the offsite resident? If yes, then evaluation, management, or remediation is necessary If no, then no further remedial action is necessary.

2.1.6 DQO Step 6: Specify Tolerable Limits on Decision Errors

Sources of uncertainties in the risk assessments will be identified and minimized

2.1.7 DQO Step 7: Optimize the Design

The nature and extent of COCs in IHSSs, PACs, UBC Sites, and WS Areas will be adequately assessed to support the CRA The nature and extent of COCs in IHSSs, PACs, and WS Areas in the IA will be determined according to the IASAP The nature and extent of COCs in IHSSs, PACs, and WS Areas in the BZ will be determined according to the BZSAP (to be completed in FY2001) The nature and extent of COCs in WS Areas across RFETS will be determined according to the IASAP and BZSAP (to be completed in FY2001) The nature and extent of COCs in BD sites will be determined using the building-specific Pre-Demolition Survey Reports If determination of the nature and extent is found to be inadequate, further sampling will be initiated

2.2 DATA QUALITY FILTER

The DQF is presented in the Preliminary Data Quality Objectives for the IASAP (DOE 2000) Data in the Sitewide environmental soil/water database (SWD) are filtered (by means of Microsoft ACCESS queries) for quality requirements prior to their use in IA activities and CRA The DQF accepts, conditionally accepts (qualifies), or disqualifies data, for use in the IA activities and CRA, based on each decision criterion described below. Descriptions of the filter criteria are consistent with associated flowcharts (Figures 13, 14, and 15 of the IASAP [DOE 2000]), starting from the upper left of the page and concluding at the lower right

The filter first segregates sample results by geographic location and then by validation qualifier Subsets of environmental data produced at RFETS were, and are currently, validated to yield three basis categories rejected, valid, and acceptable with qualification All rejected data were omitted from further use in the CRA

Analytical results are then assessed with respect to their association with validated laboratory batches Many data have no formal validation qualifiers, if these data can not be associated with laboratory batches containing other valid data, a qualification is assigned

The filter then segregates sample results by nondetected results where negative bias (result lower than expected) may be present, as indicated by the validation qualifiers. The qualifiers are not explicit as to whether the bias is positive or negative As a result, the potential for negative bias in nondetections must be identified by evaluating the qualifier reason codes for both remediation and risk assessment decisions

The sample results are then assessed with respect to approved/controlled documents used for field sampling Valid (usable) data require the use of quality controls in sample collection, a basic element of which is the use of approved and controlled procedures This filter consists of a date query that identifies samples collected in the field under approved and controlled procedures and considered to be within an established quality-controlled program.

2.3 DATA TYPES

All types of environmental media and building material will be sampled and/or surveyed to support the EU evaluation and Sitewide human health risk evaluation in accordance with this CRA Methodology Human health risks will be estimated by comparing the COC concentrations in an EU with the RFCA surface soil ALs The onsite EU assessments will be augmented with human health risks from the Sitewide air and surface water pathways Human health risks for the offsite residential exposure scenario will be assessed through the Sitewide air and the surface water pathways only Human health risks will be calculated based on the exposure scenarios, exposure pathways, and exposure routes applicable at RFETS in accordance with the CRA Conceptual Site Model (CSM) A CRA CSM has been developed for each land use described in RFCA and the wildlife refuge open space use currently being considered by the U S Congress

Contaminants are present in environmental media from primary sources and transport processes in the environment The primary sources of contaminants at RFETS are surface soil, subsurface soil, building debris, and sediments. Clean fill will be placed over the building debris before the post-closure land uses at RFETS are applicable. Therefore, the exposure pathways associated with building rubble are the same as exposure pathways associated with subsurface soil. Groundwater, surface water, and air contain contaminants due to transport processes from the primary sources

Risk and dose will be calculated from contaminants present in surface soil, sediment and surface water because receptors are directly exposed to these media (see CSM) Risk and dose will not be directly calculated from contaminants present in subsurface soil, building debris, or groundwater because an individual cannot be directly exposed to these media at RFETS Sediments are a special case an individual can be directly exposed to sediments on a pond or channel shoreline, but generally not to sediments underwater in a pond or tributary Underwater sediments may be assessed for the wildlife refuge worker scenario, if appropriate Contaminants present in surface soil and sediment can be resuspended in air and transported Inhalation exposures will be assessed for surface soil and sediments. COCs present in subsurface soil, building debris, groundwater, and sediment can be transported to surface water where human health risks will be estimated

Surface soil and sediments will be sampled to support the HHRA due to direct ingestion of soil/sediment, dermal contact from soil/sediment, inhalation of resuspended soil/sediment, and external irradiation from soil/sediment exposure pathways

Contaminant concentrations in air will be modeled to support the HHRA due to direct inhalation Air contaminant concentrations will be determined from the Sitewide surface soil and sediment contaminant concentrations by environmental transport modeling to support the calculation of human health risks for the CRA Integrated Monitoring Plan (IMP) data will be used for model validation

Surface water will be modeled to support the human health risk assessment due to direct ingestion of surface water and dermal contact with surface water. Surface water contaminant concentrations will be determined from surface soil, subsurface soil, building debris, groundwater, and sediment contaminant concentrations by environmental transport modeling Contamination present in surface water from surface water runoff and erosion will be

modeled to support the calculation of human health risks for the CRA IMP surface water data will be used for model validation

Contaminants present in groundwater can contribute to contamination in surface water through seeps Therefore, groundwater contaminant concentrations will be determined from sampling data and modeling of subsurface contaminant concentrations Groundwater transport of contaminants will be modeled to support the calculation of human health risks for the CRA The leaching of contaminants present in subsurface soil and building debris to groundwater, and subsequent movement to surface water, will be modeled to support the assessment of human health risks for the CRA

Contaminants present in sediments contribute to contamination in surface water through dissolution and resuspension Sediment interactions with surface water will be modeled to support the calculation of human health risks for the CRA

All types of environmental media and building material will be sampled, surveyed, and analyzed to support the CRA requirements Sampling results will be compared to modeling results to ensure that model predictions are satisfactory Surface soil, subsurface soil, building debris, groundwater, surface water, and sediments will be sampled, surveyed, and analyzed

2.4 DATA AGGREGATION FOR RISK ASSESSMENT

Sampling and modeling contaminant data for onsite environmental media that meet the DQO and DQF requirements will be used to estimate human health and ecological risks on an EU basis, augmented with Sitewide air and surface water assessments An EU is the area in which an individual is expected to be exposed to contaminants in surface soil and sediments, and is dependent on the exposure scenario (Section 5.2.2). Human health risks will be calculated for an offsite resident using Sitewide air and surface water analyses The types of data aggregation to be performed for the HHRA are outlined in Table 2-1 below

Table 2-1 Data Aggregation for HHRA

Exposure Scenario/ Exposure Area Basis	Exposure Unit	Sitewide Air Pathway Analysis	Sitewide Surface Water Pathway Analysis
Onsite Office Worker	X	X	
Onsite Open Space Visitor	X	X	X
Onsite Wildlife Refuge Worker	X	X	X
Offsite Resident		X	X

Data for surface soil, subsurface soil, building debris, groundwater, and sediments will be aggregated on a Sitewide and EU basis to estimate exposure concentrations and intakes to perform the CRA

17

2.4.1 Industrial Area Exposure Unit Development

An EU size of 30 acres is designated for areas of RFETS identified as light industrial land use, based on an analysis of established industrial area sizes in Boulder, Colorado The value of 30 acres was derived from the following data summarized from data displayed on Figure 2-1

- There are 15 established industrial areas in Boulder
- The average industrial area size, based on all 15 established industrial areas, is 61 9 acres
- The 61 9-acre average includes one very large industrial area of 489 2 acres When the 489 2-acre area is omitted from the calculation, the average industrial area size is 31 4 acres
- The median industrial area size, based on all 15 industrial areas, is 32.1 acres
- An area of 30 acres for the office worker scenario was used in previous risk assessments at RFETS

Data will be aggregated for EUs of 30 acres to calculate exposure concentrations for the office worker scenario

2.4.2 Open Space Wildlife Refuge Worker Exposure Unit Development

An EU size for the wildlife refuge worker scenario will be determined after more details about the planning for the proposed RFETS wildlife refuge land use is known

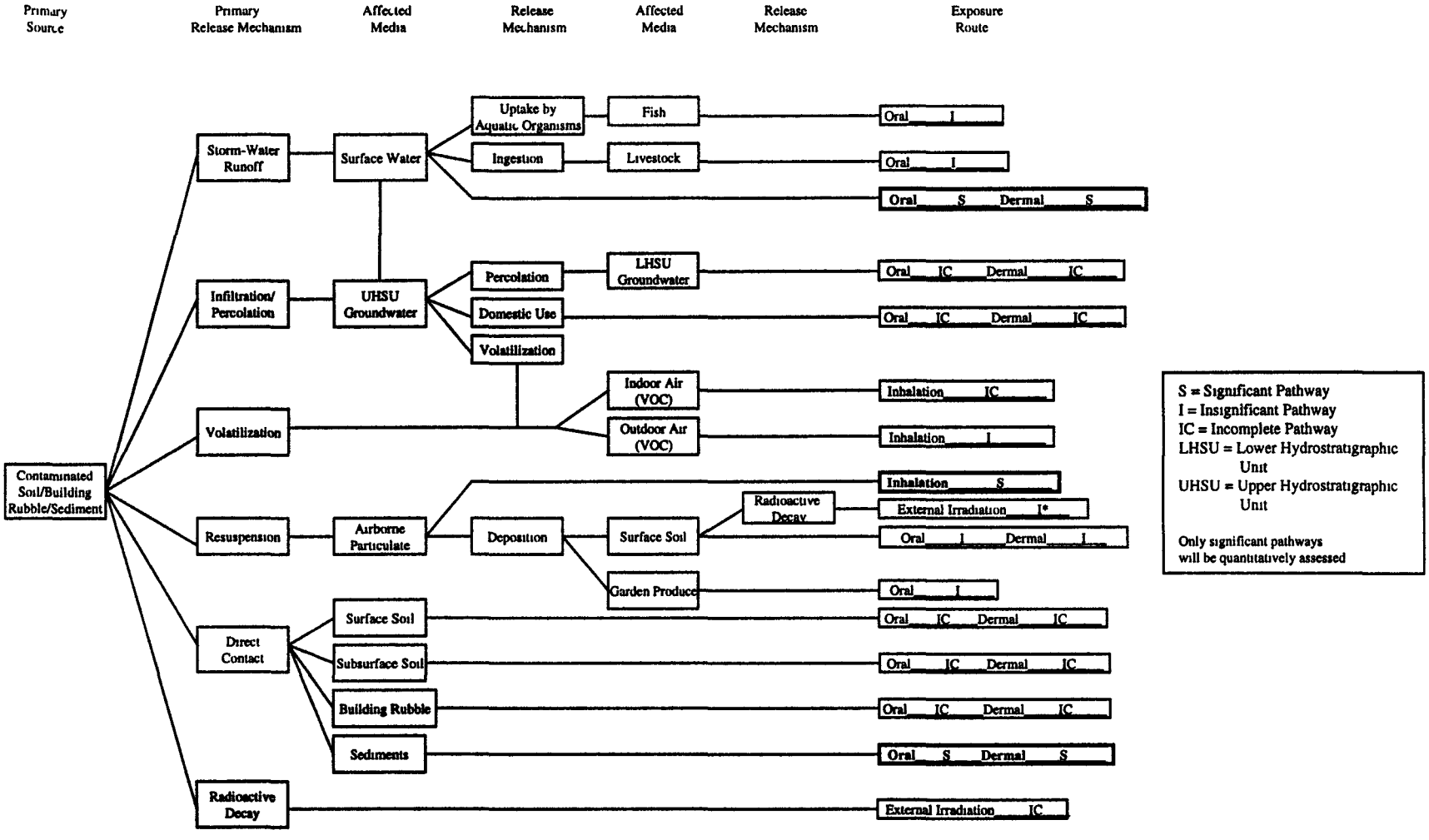
2.4.3 Recreational Open Space Visitor Exposure Unit Development

The EU area associated with the recreational open space land use is very large The scenario is based on open space usage data for Jefferson and Boulder Counties for hikers, bikers, and runners The true extent of this EU could encompass all IHSSs and PACs at RFETS The size of the EU will be decided through discussions with CDPHE and EPA for the final methodology

2.4.4 Data Aggregation for Sitewide Pathways

There will be no EU designated for the offsite residential exposure scenario for several reasons 1) All COCs will be transported to the offsite resident (Figure 2-2), and 2) offsite environmental media data will not be collected to assess human health risks to the offsite resident This data has already been collected and assessed Therefore, it is not appropriate to designate an EU for the offsite resident.

Figure 2-2 Offsite Residential Exposure Scenario



*This exposure route is insignificant because a small fraction of radioactive material is resuspended and subsequently deposited on soil

20

3.0 HUMAN HEALTH CHEMICAL OF CONCERN IDENTIFICATION BY SITEWIDE UNIT AND EXPOSURE UNITS

Chemical of concern (COC) selection and accompanying toxicity assessments for human health are described below COCs will be carefully selected to ensure that risk is assessed for the contaminants most likely to cause harm upon human contact The appropriate transport mechanisms and EUs for the COCs are described below in Section 4 0 Toxicity assessments describe the potential detriments to human health when COCs are contacted

This section describes the methodology used to identify a list of COCs in each environmental medium that may pose human health hazards (EPA 1995) Once identified, COCs will be used in the quantitative risk assessment to characterize risk for potential future human receptors

3.1 SELECTION OF CHEMICALS OF CONCERN

COCs will be identified on a Sitewide basis and an EU basis The Sitewide COC list will be developed first Exposure Unit -specific COC lists will be based on areas that contain chemicals, metals, and radionuclides above the RFCA Tier II AL The most restrictive of the three potential land uses (industrial office space, open space, and wildlife refuge) will be used Individual EUs will have specific COCs, because historical use of chemicals varied across the Site The EU-specific COC lists will eliminate unnecessary risk calculations, and customize the PPRG screens.

Data will be aggregated on a Sitewide basis by medium and analyte prior to initiation of the screening process A summary presentation of the data will include

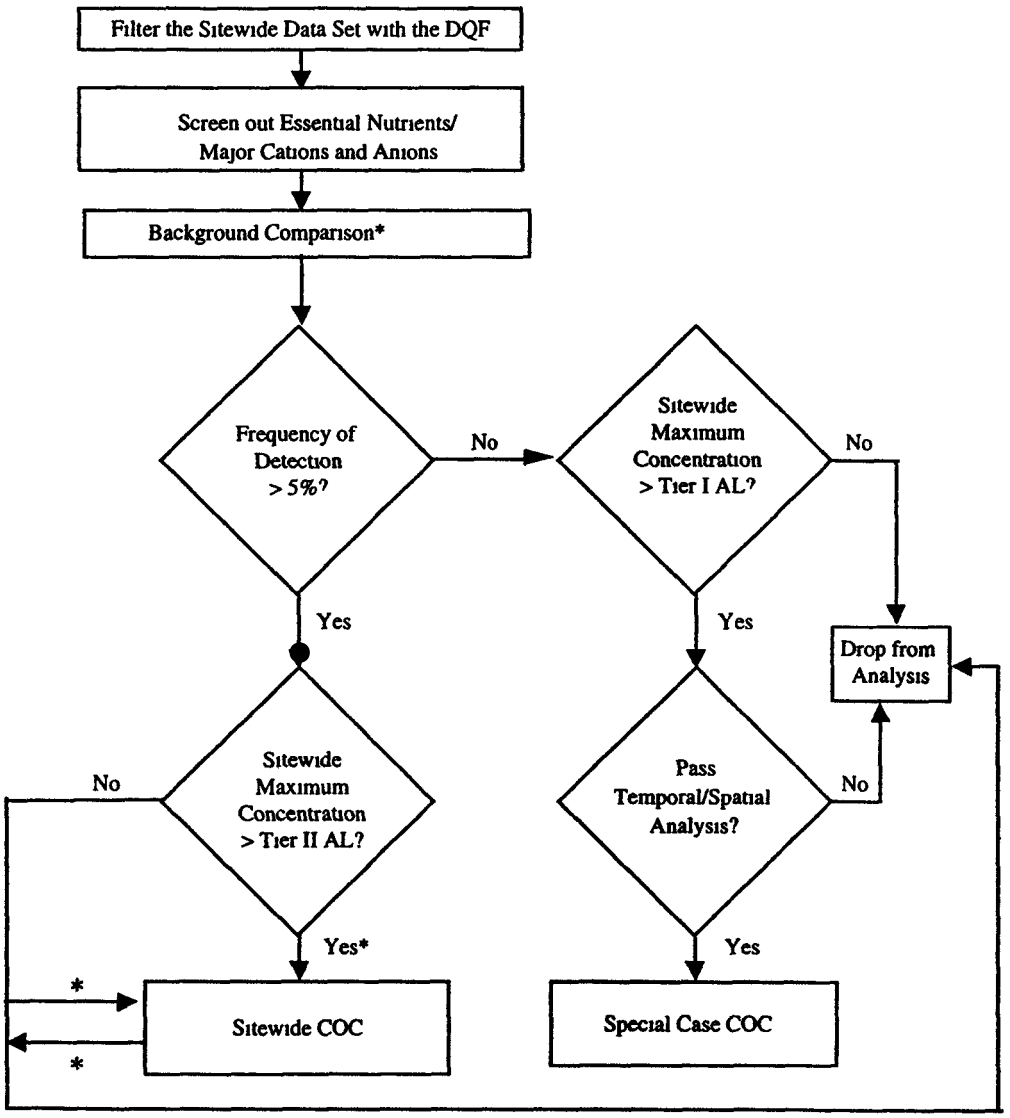
1 Chemical name,
2 Chemical-specific contract-required quantitation limit (CRQL),
3 Reported detection limit,
4 Frequency of detection,
5 Minimum detected concentration,
6 Maximum detected concentration, and
7 Arithmetic mean concentration

The selection of COCs will follow the stepwise process outlined on Figure 3-1. At each decision point, a chemical will be eliminated or retained for further consideration All analytes under consideration will be referred to as potential chemicals of concern (PCOCs) until the last step of the selection process has been completed The process begins with all available environmental data for the entire Site Environmental media that will be included in the COC selection process are surface soil, subsurface soil, groundwater, and sediment. The PCOCs passing the DQF, described in Section 2 2, will be screened to eliminate essential nutrients and major cations and anions that pose no health risks A background comparison to distinguish sample data above background concentrations will then be performed on inorganics and radionuclides Next, temporal and spatial analyses will be performed on analytes with less than 5 percent detection frequencies and Sitewide maximum concentrations greater than the Tier I ALs to determine whether they will be considered a "special case COC " If the detection frequency for an analyte is greater than 5 percent, the analyte's maximum Sitewide concentration will be compared to the

21

Tier II ALs If the concentration is greater than the Tier II AL, the analyte will be considered a PCOC All deletions and additions will be examined using professional judgement to complete the COC list Each step in the CDC identification process is described in detail in Sections 3 1 1 through 3 1 7

Figure 3-1
COC Identification Process



* Professional judgement applied to these evaluations

22

3.1.1 Data Quality Filter

The DQF is described in Section 2 2 All available Site environmental analytical data for each medium (subsurface soil, surface water, groundwater, and sediments) will go through a series of queries to ensure the following

- Validation qualifiers are appropriate If they are not present, association with validated laboratory batches will suffice (A distinct data qualifier used to identify data as such)
- Potential negative biases in nondetections have been assessed for accuracy
- Approved and controlled procedures in the field were in use for sample collection

3.1.2 Elimination of Essential Nutrients/Major Cations and Anions

Constituents may be eliminated from the risk assessment if they are essential human nutrients (EPA 1989a) Commonly detected chemicals considered to be an essential part of a daily human diet (EPA 1994b) include

- Calcium,
- Iron,
- Magnesium,
- Potassium, and
- Sodium

Other essential nutrients may be added to this list through consultations with EPA and the State

Nitrate, nitrite, ammonium, and fluoride have oral toxicological factors and are associated with water quality parameters Therefore, these four anions/cations need to be assessed in groundwater and surface water However, sulfide, bicarbonate, bromide, carbonate, chloride, orthophosphate, and sulfate have no toxicological factors and will be eliminated from assessments in groundwater and surface water Anions/cations will not be assessed in soil and sediments.

A summary table of essential nutrients, major cations, and major anions, along with their elimination status, is provided in Table 3-1

23

Table 3-1 Essential Nutrient and Major Cation/Anion Elimination from Risk Assessment

Analyte Category	Assess for Risk?	Reason
Essential Nutrients		
Calcium	No	Essential Nutrient
Iron	No	Essential Nutrient
Magnesium	No	Essential Nutrient
Potassium	No	Essential Nutrient
Sodium	No	Essential Nutrient
Major Cations/Anions		
Nitrate	Yes	Oral toxicological factors exist
Nitrite	Yes	Oral toxicological factors exist
Ammonium	Yes	Oral toxicological factors exist
Fluoride	Yes	Oral toxicological factors exist
Sulfide	No	No toxicological factors
Bicarbonate	No	No toxicological factors
Bromide	No	No toxicological factors
Carbonate	No	No toxicological factors
Chloride	No	No toxicological factors
Orthophosphate	No	No toxicological factors
Sulfate	No	No toxicological factors

3.1.3 Background Analysis

Background analysis is the comparison used to distinguish between contamination associated with Site activities and nonanthropogenic (naturally occurring) background conditions. Professional judgement will be applied to ensure the background data set is appropriate for comparison to the Site data set (e g , geologic conditions should be similar)

The *Geochemical Characterization of Background Surface Soils Background Soils Characterization Program, Final Report* (DOE 1995a) will be used for the surface soil background data. The *Background Geochemical Characterization Report* (DOE 1993a) will be used for the remaining media types

Because the distribution of contamination onsite is not normally distributed, an Analysis of Variance (ANOVA) using a ranking method will be used to compare background concentrations to Site concentrations. This ANOVA will be performed in accordance with EPA Region VIII Superfund Technical Guidance COC Selection Process (EPA 1994b) If the concentrations for a particular analyte are found to be significantly greater than background levels, the analyte will be retained for further consideration as a PCOC

3.1.4 Detection Frequency Filter

All detected organic compounds and metals above background levels will be evaluated for their frequency of detection Compounds detected at a frequency of 5 percent or greater are considered PCOCs These analytes will be compared to Tier II ALs Compounds detected at

less than 5 percent frequency are not considered characteristic of Site contamination and the potential for exposure is low

3.1.5 PPRG Screen

Although frequency of detection is an important elimination criterion to prevent spurious data from biasing estimation of risks, an additional method will be used to prevent small areas containing high contaminant levels from being eliminated As a health-protective precaution to ensure that hot spot contaminants are not eliminated as PCOCs, all chemicals that satisfy the low frequency of detection criterion (less than 5 percent detection frequency) will be compared to Tier I ALs Tier I ALs are chemical-specific, pathway-specific, and medium-specific criteria, and are found in RFCA These values were developed using approved risk assessment methodologies and represent screening levels that should be used in a risk-based comparison

If the maximum detected value of an infrequently detected contaminant exceeds its respective Tier I AL for any pathway, the chemical will be considered a special-case COC Professional judgement will be applied to special case COCs in accordance with Section 3 1.7

Analytes with a frequency of detection greater than 5 percent will be compared to Tier II ALs to determine the analytes present on Site with concentrations greater than Tier II ALs. This is the final analytical step of the COC identification process Therefore, any analytes at this stage with concentrations greater than Tier II ALs, that also pass the professional judgement criteria section described in Section 3 1 6, will be retained as COCs

3.1.6 Professional Judgement

Professional judgement is narrowly defined for assessing PCOCs It can be used to include a chemical that did not appear to be significantly different from background based on the results of the statistical tests, but which the risk assessor believes should be included because of a preponderance of historical data suggesting the chemical may have been released in significant quantities to the environment Professional judgement can also be applied to exclude a chemical based on spatial, temporal, or pattern-recognition concepts

Professional judgement will be limited to an analysis of spatial, temporal, and pattern-recognition concepts.

1 Spatial analysis requires that concentrations of each PCOC be plotted on a map; assessment of the plotted data should indicate their presence (or absence), or any trends in concentration, and assist in delimiting hot spots

2 Temporal analysis is particularly relevant for groundwater data, where repeated sampling at a well offers the opportunity to evaluate changes in analyte concentrations over time. Time-series plots are used for this evaluation Temporal analysis of data for sediment or other geologic materials is less useful and may not even be applicable

3 Pattern recognition includes such aspects as interelement correlations, similarities in geochemical behavior, geochemical modeling to determine solubility controls on element concentrations, correlations, correlation between elemental concentrations and certain parameters (total suspended solids [TSS], the negative logarithm of the hydrogen ion activity [pH], reduction-oxidation potential [Eh or pe, where Eh=0 059*pe], clay content;

25

organic content, cation-exchange capacity, etc.), and other recognizable patterns in elemental behavior Comparison between TSS (continued) and "total" metals or "total" radionuclides should indicate whether the analyte resides in the solid (particulates or sediments) or aqueous phase (i.e , in solution) Note, however, that the human health risk is based on unfiltered samples, thus, a chemical cannot be excluded as a PCOC based on a good correlation with TSS Redox-sensitive species (sulfur, iron, vanadium, arsenic, antimony, selenium, uranium, manganese, etc) have mobilities related to Eh, in addition to pH and composition A geochemist will be consulted to evaluate these, and other, patterns of element behavior

However, with regard to TSS correlations, if the data analyst can show that TSS values in the sample markedly exceed those of background, this may be grounds for eliminating a metal or radionuclide TSS correlations will be carefully evaluated on a case-by-case basis

In addition to these forms of professional judgement, the validity of the application of statistical tests will also be evaluated For example, statistical comparison of data sets where one or both data sets have high nondetect rates or high value nondetects may well be an invalid use of the statistical tests (Gilbert and Simpson 1992) As noted by Helsel (1990), " the fabrication of data followed by a t-test must be considered too arbitrary for use especially for legal or management decision purposes, and should be avoided " The "fabrication of data" here is the same as "replacement of nondetect data" (i e , replacement with a value such as one-half the detection limit, or a value generated by maximum likelihood estimation calculations) Helsel (1990) defines a "small" amount of censoring as less than 20 percent nondetects, a "moderate" amount of as 20 to 50 percent nondetects, and a "large" amount as greater than 50 percent nondetects (Note "censored" is used here in the statistical sense, as indicating those data below the analytical detection limit These data are used by replacement with a proxy value, such as one-half the detection limit, or given a ranking in nonparametric tests) However, there is an inherent uncertainty of statistical test results procured using data sets with greater than 50 percent nondetects.

In addition to high nondetect rates invalidating the results of statistical tests, other potential pitfalls in the application of statistical tests include violation of distributional assumptions, variance assumptions, data independence assumptions, etc If parametric tests are used, the data sets will be normally distributed and have approximately equal variances

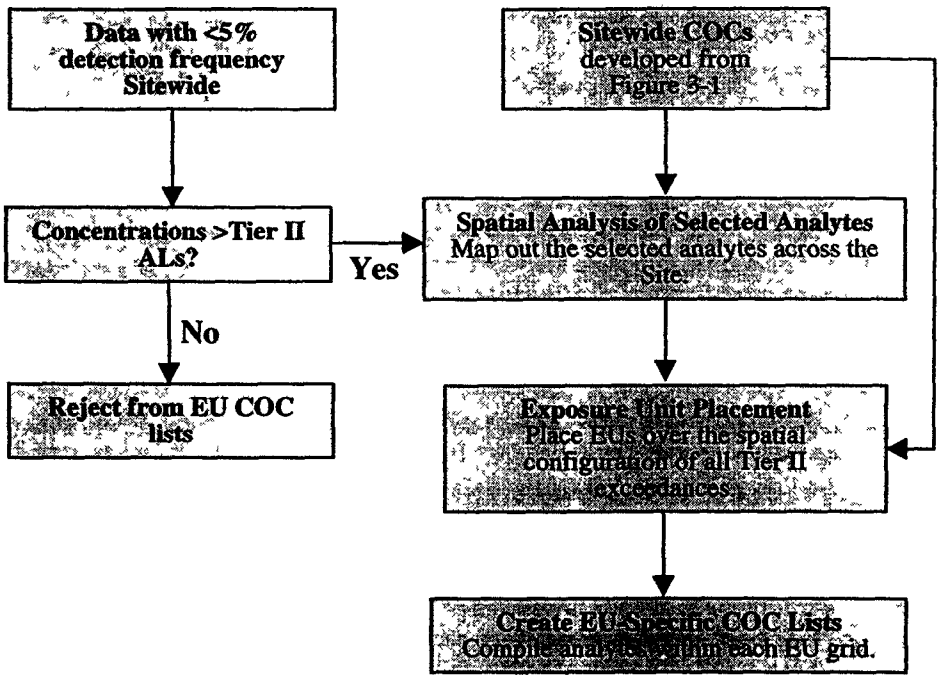
In summary, professional judgement will be applied on a case-by-case basis All such judgment will be backed up by thorough analysis of the available evidence Maps, figures, and references supporting the professional judgement will be included in the written evaluation

3.1.7 EU-Specific COC Development

EU-specific COCs will be developed by selecting all Sitewide COCs with detection frequencies greater than 5 percent and concentrations greater than Tier II ALs All detections with frequencies <5% Sitewide will be screened against Tier II ALs and analyzed spatially for inclusion as COCs (Figure 3-2) The associated sample locations will be spatially oriented, and EU grids will be placed on top of the locations with the filtered COCs Each EU's individual list of anlalytes will then be compiled

26

Figure 3-2 Exposure Unit-Specific COC Development



3.1.8 Presentation of Chemicals of Concern

Examples of summary tables that will be developed as part of the COC selection process are presented in Tables 3-2 and 3-3 Table 3-2 will summarize data for each analyte and will be provided for each applicable medium Table 3-3 will document the results of the COC selection process for each analyte, including the following information:

- Whether the analyte is significantly above or below background concentrations,
- Whether the analyte is an essential nutrient,
- Its detection frequency,
- Results of the spatial and temporal analysis,
- Results of the Tier I and II AL screens; whether the analyte is a special-case COC, and
- Whether the analyte is a COC

21

Table 3-2 Data Summary for COC Selection by Environmental Media

Analyte	Background (unit)	Essential Nutrient	Frequency of Detection	Tier I Action Level Screen	Spatial and Temporal Analysis	Tier II Action Level Screen	Special-Case COC	COC
Inorganics								
Organics								
Radionuclides								
Notes								

Table 3-3 COC Selection, Rationale for Selecting COCs

Analyte	Background (unit)	Essential Nutrient	Frequency of Detection	Tier I Action Level Screen	Spatial and Temporal Analysis	Tier II Action Level Screen	Special-Case COC	COC
Inorganics								
Organics								
Radionuclides								
Notes								

28

4.0 HUMAN HEALTH TOXICITY ASSESSMENT FOR CHEMICALS OF CONCERN

Toxicity values are used to characterize risk, while toxicity profiles summarize toxicological information for radioactive and nonradioactive COCs Consistent with Risk Assessment Guidance for Superfund (RAGS) Part A (EPA 1989a), toxicity information is summarized for two categories of potential effects noncarcinogenic and carcinogenic These two categories have slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens The toxicity assessment section of this Methodology discusses obtaining toxicity values and developing toxicity profiles (for those COCs listed in EPA's *Integrated Risk Information System* (IRIS) or *Health Effects Assessment Summary Tables* (HEAST)

The toxicity values used quantitatively in the HHRA will be obtained from two major sources The primary source of information is EPA's IRIS (EPA 2000a) IRIS contains only the toxicity values that have been verified by EPA's Reference Dose or Carcinogen Risk Assessment Verification Endeavor (CRAVE) Work Groups The IRIS database is updated monthly and, in accordance with RAGS (EPA 1989a), supercedes all other sources of toxicity information

If the necessary data are not available in IRIS, EPA's most recent issue of HEAST (EPA 1997a) will be used It contains a comprehensive listing of provisional risk assessment information that has undergone review and has the concurrence of individual EPA Program Offices, but has not had enough review to be recognized agency-wide as consensus information (EPA 1997a) Values that have been withdrawn will not be used quantitatively unless an EPA Region VIII toxicologist concurs with their use for RFETS risk assessment HEAST will not be used for radionuclide slope factors Federal Guidance Report No 13 (Section 4 1.2) will be used as guidance for calculating radionuclide-specific cancer risk (EPA 1999a) Route-to-route extrapolation of toxicity values will not be performed at RFETS except where oral criteria are used for dermal exposures

Secondary sources of information will be used qualitatively in the HHRA EPA toxicologists, both regional and national, may also serve as information sources and provide contact to the Environmental Criteria and Assessment Office for provisional values All information sources will be documented in the toxicity assessment

4.1 IDENTIFICATION OF TOXICITY VALUES FOR CARCINOGENIC EFFECTS

Potential carcinogenic risks will be expressed as an estimated probability that an individual might develop cancer from lifetime exposure This probability is based on projected intakes and chemical-specific dose-response data called cancer slope factors (CSFs) CSFs and the estimated daily intake of a compound, averaged over a lifetime of exposure, are used to estimate the incremental risk that an individual exposed to that compound may develop cancer. There are two classes of potential carcinogens chemical carcinogens and radionuclides For the purposes of toxicity assessment, each of these two classes of elements or compounds are discussed separately below

4.1.1 Chemical Carcinogens

Evidence of chemical carcinogenicity originates primarily from two sources· lifetime studies with laboratory animals and human (epidemiological) studies For most chemical carcinogens, animal data from laboratory experiments represent the primary basis for the extrapolation Experimental results are used to extrapolate data

- Across species (i e , from laboratory animals to humans),
- From high-dose regions (i e , levels to which laboratory animals are exposed) to low-dose regions (i e , levels to which humans are likely to be exposed in the environment), and
- Across routes of administration (e g , inhalation versus ingestion)

Federal regulatory agencies have traditionally estimated human cancer risks associated with exposure to chemical carcinogens on the administered-dose basis according to the following approach

- The relationship between the administered dose and incidence of cancer in animals is based on laboratory animal bioassay results
- The relationship between the administered dose and incidence of cancer in the low-dose range is based on mathematical models
- The dose-response relationship is assumed to be the same for both humans and animals if the administered dose is measured in the proper units

Thus, effects from exposure to high (i e , administered) doses are based on laboratory animal bioassay results, while effects associated with exposure to low doses of a chemical are generally estimated from mathematical models

For chemical carcinogens, EPA assumes a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation and tumor induction This mechanism for carcinogenesis is referred to as stochastic, which means there is theoretically no level of exposure to a given chemical carcinogen that does not pose a small, but finite, probability of generating a carcinogenic response Because risk at low exposure levels cannot be measured directly either in laboratory animals or human epidemiology studies, various mathematical models have been proposed to extrapolate from high to low doses (i e., estimate the dose-response relationship at low doses)

Currently, regulatory decisions are based on the output of the linearized multistage model (EPA 1989a) The basis of this model is that multiple events may be needed to yield tumor induction (Crump et al 1977) The linearized multistage model reflects the biological variability in tumor frequencies observed in animal and human studies The dose-response relationship predicted by this model at low doses is essentially linear CSFs calculated for nonradiological carcinogens using the multistage model represent the 95% upper confidence limit (UCL) of the probability of a carcinogenic response Consequently, risk estimates based on these CSFs are conservative

estimates representing upper-bound estimates of risk where there is only a 5 percent probability that the actual risk is greater than the estimated risk

Uncertainties in the toxicity assessment for chemical carcinogens are dealt with by classifying each chemical into one of several groups, according to the weight-of-evidence from epidemiological studies and animal studies These groups are shown in Table 4-1

Table 4-1 Carcinogen Groups

Weight-of-Evidence	Description
A	Human carcinogen (sufficient evidence of carcinogenicity in humans)
B	Probable human carcinogen (B1 - limited evidence of carcinogenicity in humans, B2 - sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans)
C	Possible human carcinogen (limited evidence of carcinogenicity in animals and inadequate or lack of human data)
D	Not classifiable as to human carcinogenicity (inadequate or no evidence)
E	Evidence of noncarcinogenicity for humans (no evidence of carcinogenicity in adequate studies)

The oral inhalation CSFs for the COCs will be compiled in a table, including the weight-of-evidence, source reference, and date In addition, as with reference doses (RfDs), the CRAVE Work Group believes that a unit conversion is required to present inhalation CSFs in the units of per $(mg/kg\text{-}day)^{-1}$ Consequently, CSFs will also be provided for the inhalation route as unit risks in units of per microgram per cubic meter $(\mu g/m^3)^{-1}$ An example of a table of carcinogenic toxicity values and supporting information is provided in Table 4-2

Table 4-2 Toxicity Constants for COCs for Carcinogenic Effects

COC	CSF Oral $(mg/kg\text{-}day)^{-1}$	CSF Inh. $(ug/m^3)^{-1}$	CSF Inh. $(mg/kg\text{-}day)^{-1}$	Weight of Evidence	Reference	Notes
Nonradionuclides						
COC 1		X	X	A	Most current applicable reference	
COC 2		X	X	B2	Most current applicable reference	
COC n		Pending	Pending	X	Most current applicable reference	
Radionuclides						
COC	**Oral CSF Risk (pCi)**	**Inhalation CSF Risk (pCi)**	**Inhalation CSF Risk (pCi)**	**Weight of Evidence**	**Reference**	**Notes**
COC 1	X	X	X	A	Most current applicable reference	
COC 2	X	X	X	A	Most current applicable reference	
COC n					Most current applicable reference	

4.1.2 Toxicity Constants for Radionuclides

A series of federal guidance documents have been issued by EPA for the purpose of providing federal and state agencies with technical information to assist their implementation of radiation

31

protection programs Federal Guidance Report No 13 (EPA 1999a) provides numerical factors, called "risk coefficients," for estimating risks to health from exposure to radionuclides This federal guidance report will be used to calculate risk from radionuclides It applies state-of-the-art methods and models that take into account age and gender dependence of intake, metabolism, dosimetry, radiogenic risk, and competing causes of death in estimating the risks to health from internal or external exposure to radionuclides It also provides tabulations of cancer risk coefficients for internal or external exposure to more than 800 radionuclides through various environmental media

Specifically, for a given radionuclide and exposure mode, both a "mortality risk coefficient" and "morbidity risk coefficient" are provided A mortality risk coefficient is an estimate of the risk to an average member of the U S population, per unit activity inhaled or ingested for internal exposures or per unit time-integrated activity concentration in air or soil for external exposures, of dying from cancer as a result of intake of the radionuclide or external exposure to its emitted radiations A morbidity risk coefficient is a comparable estimate of the average total risk of experiencing a radiogenic cancer, regardless of whether the cancer is fatal The term "risk coefficient" (with no modifier) is interpreted throughout as "mortality or morbidity risk coefficient " For conservatism, the risk coefficient associated with morbidity will be used to characterize human health risks

4.2 IDENTIFICATION OF TOXICITY VALUES FOR NONCARCINOGENIC EFFECTS

Potential noncarcinogenic effects will be evaluated in the risk characterization by comparing daily intakes (calculated in the exposure assessment) with chronic RfDs developed by EPA This section defines RfDs and discusses how they will be applied in the risk assessment

A chronic RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of the daily exposure that can be incurred during a lifetime, without an appreciable risk of a noncancer effect being incurred in human populations, including sensitive subgroups (EPA 1989a). The RfD is based on the assumption that thresholds exist for noncarcinogenic toxic effects (e.g., liver or kidney damage) RfDs are typically calculated by dividing a dose (representing a no-observed-adverse-effect level [NOAEL]or a lowest-observed-adverse-effect level[LOAEL]), at which there are no significant measurable effects produced, by an uncertainty or safety factor that typically ranges from 10 to 10,000 The RfD is rounded to one significant figure and is presented in units of mg/kg-day Thus, there should be no adverse effects associated with chronic daily intakes below the RfD value Conversely, if chronic daily intakes exceed this threshold level, there is a potential that some adverse noncarcinogenic health effects might be observed in exposed individuals

RfDs have been derived by EPA for both oral and inhalation exposures However, in January 1991, EPA replaced inhalation RfDs with reference concentrations (RfCs) RfCs are expressed in terms of concentrations in air (mg/m^3), not in terms of "dose" (mg/kg-day).

Chronic oral inhalation RfDs and RfCs for the COCs will be compiled in a table for the CRA The table will provide information on the uncertainty factors used to derive the RfDs, overall confidence in the RfD (as provided in IRIS), and target organs and critical effects that are the basis of the RfD The table will also indicate how specific inhalation RfDs are derived (e.g , through a route-to-route extrapolation from the oral RfD or extrapolation from the RfC). An

example of a table for presentation of noncarcinogenic toxicity values and supporting information is provided as Table 4-3

Table 4-3 Toxicity Constants for COCs for Chronic Noncarcinogenic Effects

COC	Oral RfD (mg/kg-day)	Inhalation RfC (mg/m^3)	Inhalation RfD (mg/kg-day	Uncertainty Factor	Overall Confidence in RfD	Target Organ/Critical Effect	Reference
COC 1	X	Pending	Pending	1,000	Medium	Liver/Hepatic Lesion	Most current applicable reference
COC 2	X	No data	No Data	1,000	Medium	Liver/Hepatic Lesion	Most current applicable reference
COC n	Withdrawn	X	No Data	10	High	Liver/Hepatic Lesion	Most current applicable reference

4.3 IDENTIFICATION OF RADIONUCLIDE DOSE CONVERSION FACTORS

Dose coefficients will be delineated according to federal guidance (EPA 1988a and 1993) These documents will be used to tabulate dose coefficients for the committed effective dose equivalent to tissues of the body per unit activity of inhaled or ingested radionuclides The reports set forth derived guides consistent with current federal radiation protection guidance The guides are intended to serve as the basis for regulations setting upper bounds on the inhalation and ingestion of, and submersion in, radioactive materials in the workplace The reports also include tables of exposure-to-dose conversion factors for general use in assessing average individual committed doses in any population adequately characterized by Reference Man (ICRP 1975)

The dose coefficients for external exposure to radionuclides distributed in air, water, and soil will be tabulated in accordance with Federal Guidance Report No 12 (EPA 1988a and 1993)

The dose coefficients are based on previously developed dosimetric methodologies and include the results of calculations of the energy and angular distributions of the radiations incident upon the body and transport of these radiations within the body Particular effort was devoted to expanding the information available for the assessment of the radiation dose from radionuclides distributed on or below the surface of the ground

Generally, dose coefficients for external exposure relate the doses to organs and tissues of the body to the concentrations of radionuclides in environmental media Because the radiations arise outside the body, this is referred to as external exposure This situation is in contrast to the intake of radionuclides by inhalation or ingestion, where the radiations are emitted inside the body In either circumstance, the dosimetric quantities of interest are the radiation dose received by the more radiosensitive organs and tissues of the body. For external exposures, the kinds of radiation of concern are those sufficiently penetrating to traverse the overlying tissues of the body and deposit ionizing energy in radiosensitive organs and tissues. Penetrating radiations are limited to photons, including bremsstrahlung, and electrons. The radiation dose depends strongly on the temporal and spatial distribution of the radionuclide to which a human is exposed The modes considered here for external exposures are

- Submersion in a contaminated atmospheric cloud, (i e , air submersion),
- Immersion in contaminated water (i e , water immersion), and
- Exposure to contamination on or in the ground (i e , ground exposure)

5.0 EXPOSURE ASSESSMENT

The exposure assessment for the CRA will quantitatively and qualitatively evaluate the contact between human receptors and chemical(s) or physical agent(s) The assessment will

- Identify potential land uses and exposed populations,
- Identify potential exposure scenarios,
- Describe the intensity, frequency, and duration of contact,
- Evaluate the rates at which the chemical(s) crosses the boundary into the receptor (intake/uptake rate), and
- Quantify the amount of the chemical(s) that crosses the boundary (intake/dose) and, when applicable, the amount absorbed (absorbed dose)

The exposure assessment also estimates the total dose or intake for a receptor in a given area for a particular land use and exposure scenario The calculated dose is then combined with chemical-specific dose-response data to estimate risk (EPA 1992b) The exposure assessment process is described in detail in the following sections

5.1 IDENTIFICATION OF POPULATIONS AND LAND USE

Potential land uses and exposed populations applicable to the Site are discussed in this section Exposure scenarios that realistically characterize the potential land uses for the Site are based on three onsite land uses light industrial/office, recreational open space, and wildlife refuge open space The offsite, near-boundary, land use is residential Exposure scenarios for these land uses are discussed below

The light industrial/office land use is currently limited to approximately 70 acres on the western end of the current IA This land use was designated in RFCA (DOE 1996a)

The recreational open space land use was also described in RFCA (DOE 1996a) It includes the entire Site, including the present IA As currently envisioned, the area would be open for public use, with hiking, running, and biking on established trails and picnicking in designated areas

A bill designating RFETS as a wildlife refuge has been proposed to the U.S Congress and is currently under consideration Access for the public would be more restricted than under the recreational open space use and is expected to be similar to that for the Rocky Mountain Arsenal (RMA) Wildlife Refuge The RMA Wildlife Refuge is a 17,000-acre, in-process wildlife refuge northeast of the Denver metropolitan area. The RMA Wildlife Refuge has a significant environmental education component with organized trips led to various portions of the site Professional research is also conducted on site by the U S. Fish and Wildlife Service It is anticipated that the most exposed individual under this land use would be the wildlife refuge worker

35

The offsite residential land use assumes a residential area immediately to the east of the site, across Indiana Street This land use has been used for previous risk assessments and for air modeling

5.2 CONCEPTUAL SITE MODELS

Information concerning contaminant sources, contaminant release and transport mechanisms, and locations and types of potentially exposed receptors is used to develop a conceptual understanding of the Site in terms of potential human exposure pathways The CSM summarizes this analysis for each exposure scenario

The CSM is a schematic representation of the contaminant source areas, contaminant release mechanisms, environmental transport media, and potential human intake routes for each type of potential human receptor The purpose of the CSM is to

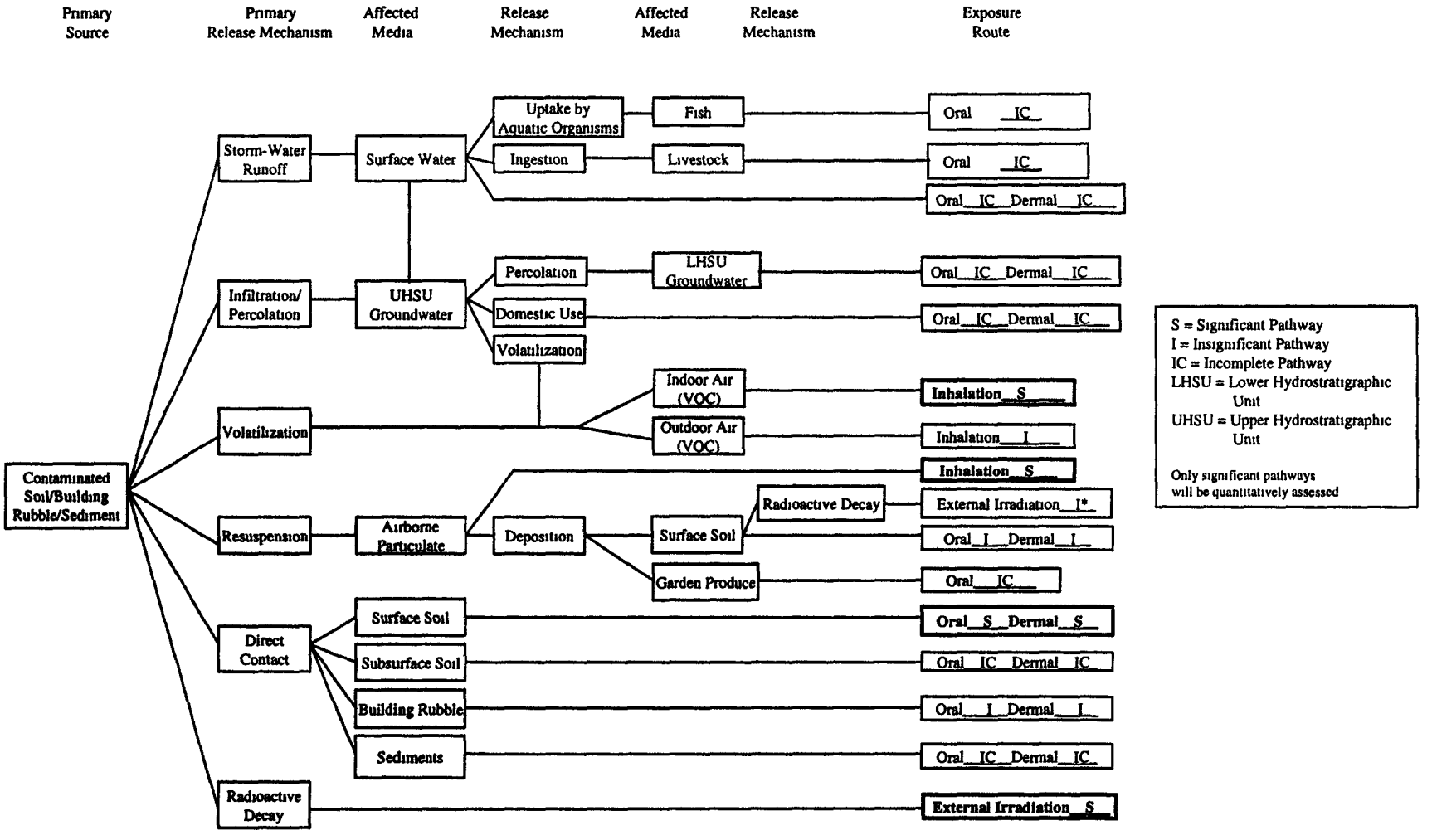
- Provide a framework for problem definition,
- Identify sources and release mechanisms,
- Identify exposure pathways that may result in human health risks,
- Aid in identifying data gaps, and
- Aid in identifying effective cleanup measures, if necessary, that are targeted at significant contaminant sources and exposure pathways

The CSMs have been developed to illustrate the exposure scenarios, exposure pathways, and exposure routes at RFETS The exposure scenarios were chosen based on the land use designations in RFCA (DOE 1996a) and the legislation introduced in the U S Congress The four exposure scenarios currently applicable at RFETS are the onsite office worker exposure scenario, onsite recreational open space exposure scenario, onsite wildlife refuge open space exposure scenario, and offsite residential exposure scenario

If mandated by U S Congress, the wildlife refuge land use will supercede both the recreational open space and light industrial land uses. Scenarios associated with each potential land use, including the wildlife refuge, are discussed in the following sections

Exposure pathways and exposure routes in the CSM have been categorized as significant, insignificant, or incomplete Significant and insignificant exposure pathways are considered complete exposure pathways with significant exposure pathways contributing the major portion of risk and dose An incomplete exposure pathway will not contribute any risk or dose A significant exposure pathway will be quantitatively assessed at RFETS while insignificant and incomplete exposure pathways will be qualitatively addressed Figures 5 1 through 5 3 define the CSMs for the office worker, open space visitor, and wildlife refuge worker scenarios, respectively The offsite resident scenario was defined in Figure 2-2 The CSMs are discussed in detail below

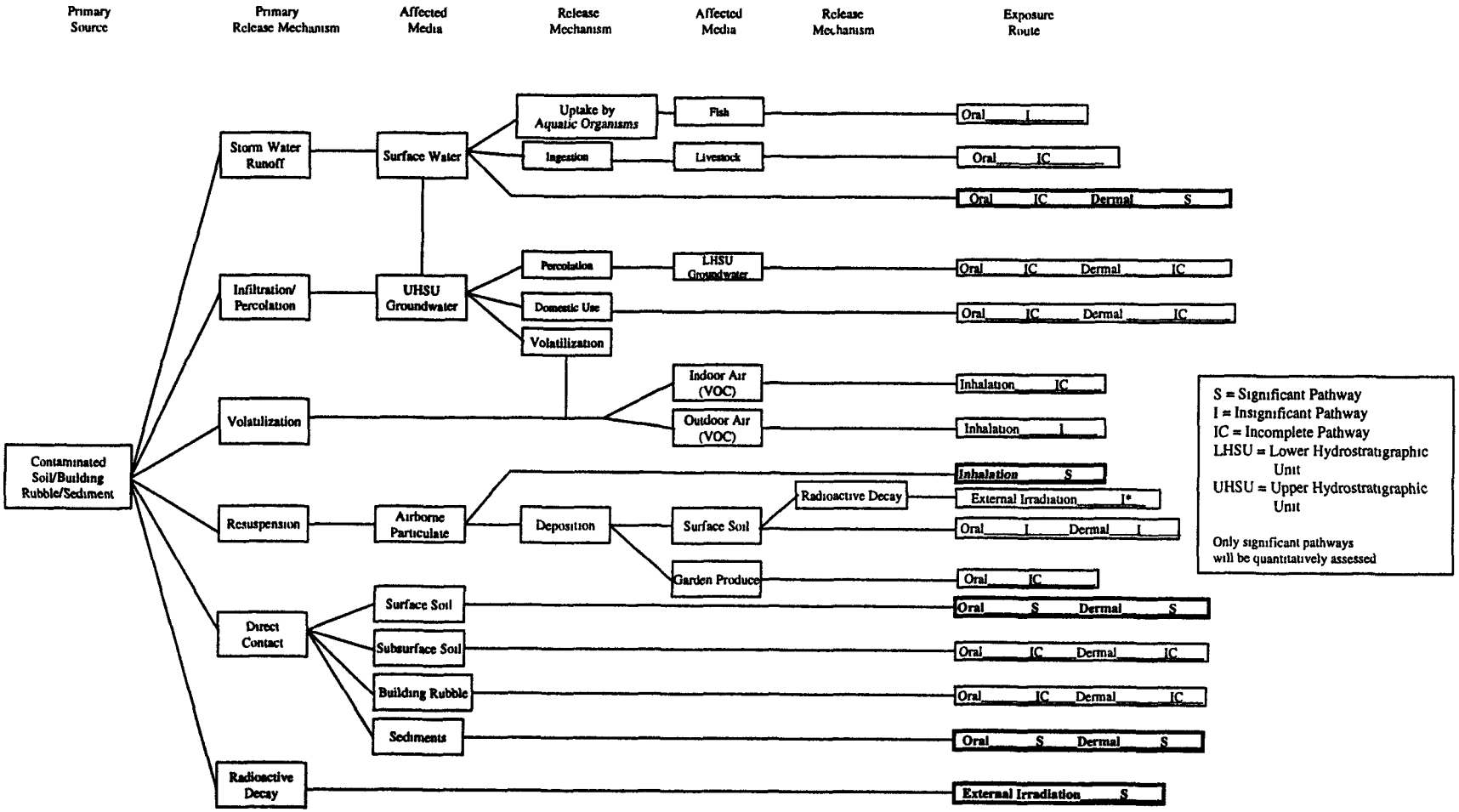
Figure 5-1 Office Worker Exposure Scenario



*This exposure route is insignificant because a small fraction of radioactive material is resuspended and subsequently deposited on soil

37

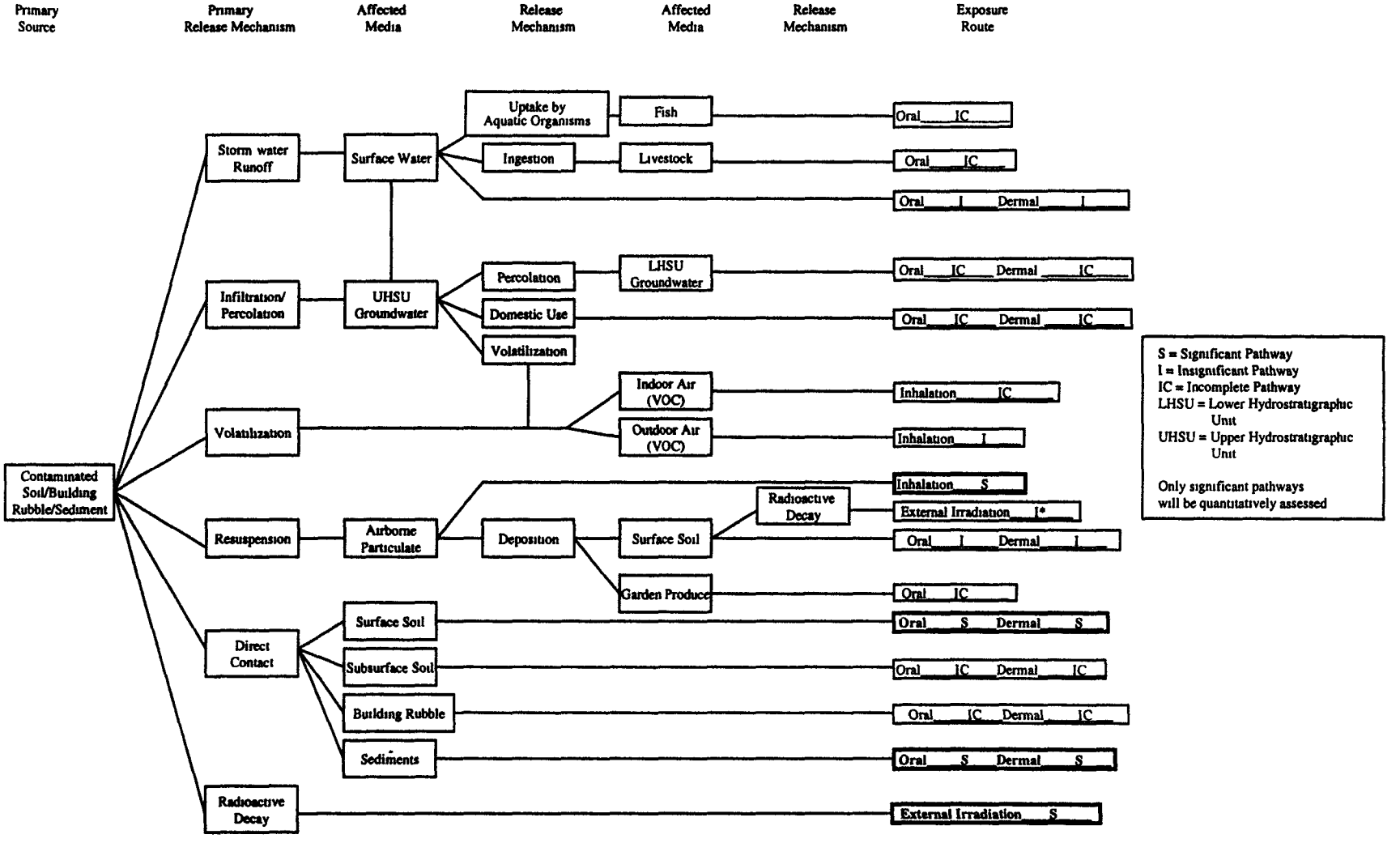
Figure 5-2 Open Space Exposure Scenario



*This exposure route is insignificant because a small fraction of radioactive material is resuspended and subsequently deposited on soil

38

Figure 5-3 Wildlife Worker Exposure Scenario



*This exposure route is insignificant because a small fraction of radioactive material is resuspended and subsequently deposited on soil

5.2.1 Exposure Pathways

An exposure pathway describes a specific environmental route by which an individual receptor could be exposed to contaminants present at or originating from a site After the primary source(s) and release mechanisms are identified for the Site, the resulting secondary sources and secondary release mechanisms are identified and described Subsequent sources and release mechanisms are identified until the exposure pathways for each contaminant are fully delineated As previously discussed, the CSM identifies potentially complete pathways for the CRA (Figures 5-1 through 5-3, and Figure 2-2) A complete exposure pathway includes five necessary elements

- Source of chemical(s),
- Mechanism(s) of chemical release,
- Environmental transport medium,
- Exposure point, and
- Human intake route

Significant, insignificant, and incomplete pathways are identified for each potential human receptor in each scenario in the CSM All potential pathways will be discussed, by scenario, in the CRA An incomplete pathway occurs when a contaminant will not come into contact with a receptor and no human exposure can occur Insignificant or negligible pathways are defined as potentially complete pathways because the contaminant can reach a receptor, but are expected to result in very low exposures with no significant impact

Significant pathways are complete pathways that involve relatively direct exposure or only moderately reduced concentrations due to contaminant fate and transport resulting in potentially complete and significant exposure Only complete and significant pathways will be quantitatively assessed in the CRA Insignificant pathways will not be quantitatively addressed in the CRA, but will be qualitatively discussed.

5.2.2 Exposure Scenarios and Exposure Units

An exposure scenario is a set of facts, assumptions, and inferences that describes the potential exposure of a particular population for a given land use, including

- Physical and temporal setting for the exposure(s);
- Exposure pathway(s) from source(s) to exposed individual(s),
- Identification of the exposed individual(s) or populations(s), and the profile of contact with the chemical(s),
- Characterization of the chemical(s) such as amounts, locations, environmental pathways, fate of chemical(s) in environment, etc.; and
- Assumptions about the transfer of the chemical to the receptor

40

Future populations on and near RFETS will be evaluated based on their likelihood of exposure to Site-related COCs EPA guidance does not require an exhaustive assessment of every potential receptor and exposure scenario (1992c) The highest potential exposures reasonably expected to occur will be evaluated, along with an assessment of any associated uncertainty (EPA 1989a) However, potential receptors will be identified and evaluated to ensure that the important receptors and exposure pathways have been assessed

Four exposure scenarios are currently under consideration for the four land uses described in Section 5 1 These are the office worker, recreational open space visitor, wildlife refuge worker, offsite resident

The office worker scenario is used in RFCA (DOE 1996a) for calculation of PPRGs and ALs for the industrial land use The basic assumptions include that the individual works indoors and has limited exposure to the surrounding outdoor environment. Typical outdoor exposures would occur during recreational walking or eating lunch outdoors

The recreational open space visitor is currently used in RFCA (DOE 1996a) for calculation of PPRGs and ALs for all other areas The recreational open space scenario was developed from data provided by Jefferson and Boulder Counties (Jefferson County 1994, 1996, Zeller et al 1993) on the use of open space trails The population is defined as hikers, runners, and bikers, using the area

A scenario for the wildlife refuge/open space land use will be developed in response to legislation to be introduced in the U S Congress by the Colorado delegation

The offsite residential scenario will be used to evaluate long-term risks to a future residential population near the Site boundary due to the potential transport of contaminants from the source areas The resident scenario will be assessed east of Indiana Street near the two streams draining offsite, Woman and Walnut Creeks.

An EU is the area in which a potential receptor can reasonably be expected to contact COCs over a specified exposure duration The size of the EU determines the area over which the COC concentrations are averaged to calculate the exposure concentration (95th upper percentile of the mean) An EU can vary in size, depending on land use, site-specific conditions, and potential receptors EUs for each exposure scenario are described in Section 2 4

An EU size for the wildlife refuge worker scenario will be determined after more details about the proposed RFETS wildlife refuge land use are known.

Office Worker Exposure Scenario

The office worker scenario is based on individuals working 8-hour shifts inside office buildings. A worker is expected to be onsite 250 days per year, 50 weeks per year (DOE 1999a)

The potential exposure pathways of plant ingestion, livestock ingestion, milk ingestion, aquatic ingestion, ground/surface water ingestion, and radon exposure are considered incomplete The pathways of soil ingestion, soil (dust) inhalation, external irradiation, dermal exposure to soil, subsoil volatile organic compounds (VOC) inhalation and VOC

41

inhalation from groundwater are applicable to the office worker exposure scenario (Figure 5-1)

The potential primary sources of contamination are soil, building rubble, and sediments (Figure 5-1) Primary release mechanisms for contaminants are storm-water runoff, infiltration/percolation, volatilization, resuspension, direct contact, and radioactive decay The contaminant pathway for each potential release mechanisms is described below

Storm-Water Runoff

The storm water pathway is incomplete for an office worker It is assumed that no contact will occur with surface water, any fish living in the ephemeral streams, or livestock grazing onsite These pathways will not be quantitatively discussed

Infiltration/Percolation

The groundwater oral and dermal exposure pathway from infiltration or percolation is not complete Groundwater present beneath RFETS does not provide enough water to support industrial domestic use (DOE 1996a)

Volatilization

The volatilization release mechanism provides a potential contaminant exposure routes to humans that includes inhalation of VOCs in indoor air Potential indoor air inhalation of VOCs is a complete pathway and will be quantitatively assessed

Outdoor air inhalation of VOCs is an insignificant pathway because office workers will spend the majority of their time indoors The volume of VOCs actually inhaled outdoors would be extremely dilute This pathway will not be quantitatively assessed

Resuspension

The resuspension mechanism provides potential contaminant exposure routes to humans that includes inhalation of airborne particulates, external radiation from surface soil with airborne particulate deposits, and oral and dermal exposure to surface soil and garden produce or wild plants

Oral and dermal exposure to resuspended soil is expected to be incidental and will not contribute significantly to dose Growing, picking, or eating plants from the Site is not considered a likely or significant pathway and will not be assessed quantitatively

External radiation from resuspended particles is an insignificant pathway because only a small fraction of particulates are resuspended and subsequently deposited on soil. This pathway will not be quantitatively assessed

Direct Contact

Direct contact with contaminated soil, building rubble, and sediments are potential pathways Subsurface soil and subsurface building rubble are unavailable for dermal contact with the office worker due to their deep location Oral ingestion and dermal exposure to sediment are incomplete pathways because office workers will not come into contact with streamside sediments These pathways will not be quantitatively assessed

Surface soil dermal exposure and oral ingestion are significant pathways and will be quantitatively assessed

Radioactive Decay
Radioactive decay from contaminated media onsite could potentially irradiate an office worker Radioactive decay from contaminated surface soil is considered a significant pathway This pathway will be quantitatively assessed

Open Space Visitor Scenario
The open space visitor scenario is based on individuals hiking, jogging, and biking in the open space area

As described on Figure 5-2, the primary sources of potential contamination to a hiker, biker, or jogger in the open space are soil, building rubble, and sediments Primary release mechanisms for contaminants are storm-water runoff, infiltration/percolation, volatilization, resuspension, direct contact, and radioactive decay The contaminant pathway for each potential release mechanism is described below

Storm-Water Runoff
Potential contaminant exposure routes to humans from storm-water runoff include the oral ingestion of fish, livestock, and surface water, and dermal contact with surface water

Oral ingestion of fish is considered an insignificant pathway, because fish found in the ephemeral streams onsite are too small to be caught and eaten by an open space visitor The A- and B-series ponds at RFETS may be filled in and eliminated before closure If the ponds are retained, it may be appropriate to assess exposures from fish ingestion Oral ingestion of contaminated livestock is an incomplete pathway because livestock are not expected to be slaughtered and eaten during a typical open space visit These two pathways will not be quantitatively assessed.

Oral and dermal contact with surface water are significant pathways for the storm-water runoff release mechanism and surface water-affected media. These pathways will be quantitatively assessed

Infiltration/Percolation
Potential contaminant exposure routes for groundwater include oral ingestion and dermal exposure to lower hydrostratigraphic unit (LHSU) groundwater and domestic use of upper hydrostratigraphic unit (UHSU) Open space visitors will not have access to groundwater, therefore oral and dermal contact with LHSU and UHSU groundwater are incomplete pathways, and these pathways will not be quantitatively assessed

Volatilization
The volatilization release mechanism provides potential contaminant exposure routes to humans that include inhalation of VOCs in indoor and outdoor air Open space visitors will not be spending time indoors on Site, so the indoor air inhalation of VOCs is an incomplete pathway Outdoor air inhalation of VOCs is an insignificant pathway because a small source volume will be mixed with large volumes of air from wind currents and natural air outdoor turbulence The concentration of any VOCs potentially inhaled will be extremely dilute, resulting in dilute contaminant levels several orders of magnitude less than significant pathways These exposure pathways will not be quantitatively assessed

Resuspension

Potential contaminant exposure routes from resuspension include inhalation of airborne particulates and oral, dermal, and external radiation from airborne particulates redeposited in surface soil and on plants

Inhalation of airborne particulates is a significant pathway and will be quantitatively assessed

Oral ingestion and dermal exposure to surface soil containing airborne particulates is an insignificant pathway because the relative concentration of redeposited material would be small Oral ingestion of wild plants is considered an incomplete pathway because open space visitors will be discouraged from ingesting plants growing onsite while visiting open space Any incidental exposure would be minimal, resulting in dilute contaminant levels several orders of magnitude less than significant exposures

External radiation is an insignificant pathway because only a small fraction of radioactive material is resuspended and subsequently deposited on soils, this pathway will not be quantitatively assessed

Direct Contact

Direct contact is a potential pathway for contaminants associated with surface soil, subsurface soil, building rubble, and sediments. Subsurface soil and subsurface building rubble are unavailable for dermal contact with the open space visitor, and the pathways are incomplete These pathways will not be quantitatively assessed Oral ingestion and dermal exposure are significant pathways for surface soil and sediment These pathways will be quantitatively assessed

Radioactive Decay

Radioactive decay from contaminated primary sources could potentially irradiate an open space visitor Subsurface soil and subsurface building rubble are unavailable for contact with the open space visitor and the pathways are incomplete These pathways will not be quantitatively assessed Radioactive decay from contaminated surface soil is considered a significant pathway This pathway will be quantitatively assessed

Wildlife Refuge Worker Exposure Scenario

The exposure pathway analysis and EU size for the wildlife refuge worker scenario will be determined after more details about the proposed RFETS wildlife refuge land use is known

Offsite Resident Exposure Scenario

The offsite resident scenario is based on several assumptions Individuals have garden plots and produce is used for a portion of their diets throughout the year. It is assumed the resident lives and eats at their home 50 weeks or 350 days per year (DOE 1996a)

The primary sources of potential contamination are soil, building rubble, and sediments (Figure 2-1) The potential primary release mechanisms for contaminants are storm-water runoff, infiltration/percolation, volatilization, resuspension, direct contact, and radioactive decay An offsite resident could be exposed to contamination through oral ingestion, dermal contact, inhalation, and external radiation.

44

The aquatic food ingestion pathway and groundwater ingestion exposure pathway are not considered complete pathways for the future offsite resident and will not be considered The meat and milk ingestion exposure pathways are considered insignificant and will not be considered quantitatively

The soil ingestion, soil inhalation, external irradiation, and vegetable consumption exposure pathways will be assessed for an offsite residential receptor The contaminant pathway for each potential release mechanism is described below

Storm Water Runoff

Potential contaminant exposure routes to offsite residents include the oral ingestion of fish and livestock, and oral and dermal exposure to surface water. Oral ingestion of fish is an insignificant pathway, because the fish found in the ephemeral streams originating onsite are too small to realistically be caught and eaten by an offsite resident. The A- and B-series ponds are expected to be removed at Site closure If they remain after closure, their contribution to the offsite residents' consumption of fish may be assessed Oral ingestion of butchered livestock is an insignificant pathway because offsite residents will not be consuming livestock grazing on their property as a major portion of their diet These two pathways will not be quantitatively assessed

Oral and dermal contact with surface water are significant pathways for the storm-water runoff release mechanism These pathways will be quantitatively assessed

Infiltration/Percolation

Potential contaminant exposure routes for groundwater include oral ingestion and dermal exposure to LHSU groundwater and domestic use of UHSU groundwater The oral and dermal pathways for LHSU and UHSU groundwaters are incomplete There is no known transport of contaminants offsite from sources onsite in groundwater These pathways will not be quantitatively assessed

Volatilization

The volatilization release mechanism provides potential contaminant exposure routes that include inhalation of VOCs in indoor and outdoor air Indoor air inhalation of VOCs is an incomplete pathway There is no offsite source and no known transport of contaminants offsite from sources onsite in groundwater Outdoor air inhalation of VOCs is an insignificant pathway because a small source volume from onsite will be mixed with large volumes of air The concentrations of VOCs potentially inhaled would be extremely dilute, resulting in insignificant exposure levels. These pathways will not be quantitatively assessed

Resuspension

The re-suspension mechanism provides potential contaminant exposure routes that include inhalation of airborne particulates, oral and dermal exposures, and external radiation from surface soil containing airborne particulate deposits

Inhalation of airborne particulates is considered a significant pathway and will be quantitatively assessed

45

Oral ingestion, dermal exposure, and external radiation to airborne particulates deposited in surface soil are insignificant pathways (DOE 1999a, K-H 1999, 2000a) Exposure is expected to be extremely low, the pathway will not be assessed quantitatively

Oral ingestion of wind-borne contamination deposited on garden produce is an insignificant pathway because of the small deposition component (DOE 1999, K-H 2000a) Any incidental exposure would be extremely minimal and the pathway will not be quantitatively assessed

Direct Contact

Direct contact with surface soil, subsurface soil, building rubble, and sediments are potential pathways The pathways for direct contact with subsurface soil and subsurface building rubble are incomplete for the offsite resident These pathways will not be quantitatively assessed

Offsite residents may be exposed directly to onsite surface soil and sediments if the Site is designated as recreational open space These pathways will be assessed if appropriate Residential exposures to offsite surface soil and sediments have been assessed in the OU 3 RFI (DOE 1996b) As such, these exposures will not be assessed quantitatively again

Radioactive Decay

Radioactive decay from contaminated surface soil onsite may be considered a significant pathway if the Site is designated as recreational open space This pathway will be quantitatively assessed if appropriate

5.3 FATE AND TRANSPORT MODELING

Fate and transport modeling is used to estimate contaminant concentrations at the point of contact when observational data are not available Fate and transport models use a combination of processes, relationships, and site-specific information to estimate concentrations of chemicals in various environmental media Concentrations that may be estimated include, but are not limited to the distribution of concentrations over media, space, and time, indoor air levels of chemicals, concentrations in foods; and so forth. When available, valid analytical measurements take precedence over modeled estimates.

Models are computer codes or sets of equations that can be used to represent site conditions and the transport of COCs in soil gas, groundwater, surface water, and air The models incorporate site-specific data, estimates derived from site-specific data, and interpretations of the data The combination of a computer code and site-specific data is a site-specific model

Models selected should be capable of incorporating key COC transport and transformation processes and simulating the important domain characteristics and material/fluid properties The following five categories should be considered when selecting models for use

- Ability to adequately simulate RFETS conditions,
- Ability to satisfy the objectives of the study,
- Verification of the model using published analytical equations,

- Documentation, peer-review, and availability, and
- Practicality and cost-effectiveness

5.3.1 Modeling Criteria

The following is a summary of the modeling criteria that have been identified during the RFETS Actinide Migration Evaluation (AME) project used to adequately substantiate the quality of the Site modeling effort The modeling criteria identified in this summary are the categories of applicable requirements that have been excerpted from *Fiscal Year 2000 Actinide Migration Evaluation Data Quality Objectives, Revision 2* (K-H 2000b) The modeling efforts will be an important component of the overall regulatory closure of the Site and will impact remedial approaches and the CRA The modeling results will undergo intense scrutiny by the Site, stakeholders, and regulatory agencies The modeling criteria categories applicable to the Site modeling effort include sensitivity and uncertainty analysis, calibration, and verification and validation activities, as described below

Sensitivity and Uncertainty Analysis
Model sensitivity and uncertainty analysis may encompass all input parameters, including "derived" parameters (those that may be varied in the calibration process), and "measured" parameters (those that are estimated and then left fixed throughout the simulations) The sensitivity and uncertainty analysis will be performed in accordance with the DQO criteria A description of these activities and results of the evaluations will be presented with the modeling results

Calibration
Model calibration is an iterative process of parameter adjustment such that model output satisfactorily estimates a set of real-world data A calibration of the all models will be performed in accordance with the DQO criteria A description of the calibration processes and comparisons of predicted values to Site monitoring observed data, whenever possible, will be provided with the results of all models

Model Verification and Validation Activities
The process of model verification and validation (assessment of model adequacy) includes assessing all aspects of the model's assumptions, inputs, outputs, sensitivities, and uncertainty, with particular emphasis on calibration results and limitations. Verification and validation of the Site models will be performed in accordance with the DQO criteria. A description of the verification and validation activities, including the results of comparisons to observed Site monitoring data, will be presented with modeling results, and uncertainty associated with the model predictions will be discussed and quantified, if possible

Model Implementation
Considerations for implementing a model include

- Availability of and confidence in input data that will support the model,
- Availability of the model,

47

- Degree and nature of documentation,
- Extent of peer review of the model;
- Nature of model verification, validation, and testing,
- Computer systems on which the model has been used; and
- User familiarity with the model

The following sections describe types modeling that may be used in the CRA

5.3.2 Conceptual Site Model and Modeling Needs and Objectives

The CSM is used to evaluate exposure pathways by their potential contribution to exposure Significant pathways will be examined to determine whether there is sufficient data to calibrated exposure or whether modeling is required to estimate contaminant concentrations

Pathways involving direct exposure to sources will use measured sources The goal of fate and transport modeling is to simulate contaminant migration from source areas in soil, groundwater, surface water, sediments, and air to potential onsite and offsite receptors. Pathways resulting from source release mechanisms may require fate and transport modeling (e g , resuspension of subsequent airborne-contaminated soil and transport offsite)

Overview of Models and Data Needs
The following sections provide an overview of the modeling specific to contaminants in soil gas, groundwater, surface water, and air When specific models are selected for use at RFETS, the assumptions and limitations associated with each model and its application will be identified and documented The following four sections discuss soil-gas transport, groundwater, surface water, and air modeling

Soil Gas Transport
The objective of soil gas modeling is to predict the transport and resulting concentrations of contaminants in air to predict receptor exposures via the soil gas pathway The soil gas pathway is especially important for UBC. Examples of data needed for a soil gas model(s) that may or may not require assumptions include

- Properties of the site such as soil porosity, water content, and hydraulic conductivity,
- Environmental properties such as relative humidity,
- Building characteristics such as pressurization and ventilation rate; and
- Chemical-specific properties such as vadose zone concentration, groundwater concentration, solubility, Henry's law constant, and biodegradation rate

Groundwater
The primary processes that control and are used to predict the movement of solutes in the subsurface include groundwater flow rates and directions, solute release rates and timing,

48

recharge and discharge rates, dispersion, degradation rates, and adsorption Groundwater modeling must address both unsaturated flow (vadose zone) and saturated flow (groundwater) Vadose zone and groundwater modeling should consider site-specific conditions, the location(s) of the groundwater flow, recharge and discharge, primary source(s) of contamination, boundary conditions, and material types Examples of data required for the modeling effort include

- Horizontal and vertical hydraulic conductivity,
- Water storage,
- Porosity;
- Residual and saturated moisture content,
- Molecular dispersion,
- Retardation, and
- Degradation

Surface Water

The purpose of surface water modeling is to estimate the potential concentration of contaminants in associated surface water locations at RFETS. The potential for future transport of contaminants by runoff and erosion has been evaluated by the AME using the Watershed Erosion Prediction Project (WEPP) model (K-H 2000a) The erosion model was coupled with the Sedimentation in Stream Networks model (*HEC6-T) to predict sediment movement in stream channels Techniques were developed to estimate the transport of actinides with sediments These models are used to estimate the transport of contaminants associated with the solid phase Another model may be developed to estimate the movement of dissolved contaminants Assumptions associated with surface water modeling include

- Drainage basins,
- Area of contaminated soil,
- Contaminant concentrations in soil,
- Contaminant solubility,
- Rainfall,
- Hydraulic conductivity,
- Soil erodibility,
- Vegetation, cover, and management,

- Hillslope characteristics,
- Stream channel characteristics, and
- Base flow

Air

The objective of air modeling is to provide estimates of emissions, dispersion, surface deposition, and fate of contaminants released from the Site Both near-field and far-field scenarios have been developed for the Site Far-field models are more complex and include most of the requirements of near-field models, with the addition of transport, dispersion, and deposition of contaminants An air model has been developed for the Site by the AME (K-H 1999, 2000a) This model has been applied to current Site conditions and can be used for post remediation conditions Site characteristics that require simulation include

- Meteorological conditions,
- Dispersion assumptions,
- Special conditions;
- Time domain, and
- Terrain characteristics

Conditions at the receptor, which must also be represented by the model, include

- Height of receptor,
- Location,
- Exposure pathways,
- Occupancy factors, and
- Consumption or usage

5.4 IDENTIFYING EXPOSURE UNITS AND EXPOSURE POINT CONCENTRATIONS

After COCs and EUs have been identified, EPCs are estimated for each COC in each environmental medium All COC data within an EU will be aggregated over the appropriate exposure area. The EPC is the 95% UCL of the mean concentration of a contaminant to which a receptor is expected to be exposed EPCs will be calculated for the significant, complete pathways shown in the CSM Steps in the exposure area procedure include

1 Determine the size of the EU for each scenario by considering the receptors and exposure pathways EU areas for RFETS are discussed in Section 2 0

50

2 Plot all COC data, including data below background or detection limits, on a map of the Site

3 Place EU grids by considering COC concentrations, contaminated environmental media, and potential exposure pathways

4 Analyze data within the exposure area using the complete COC data set as determined using the methods in Section 2 0

5.5 EXPOSURE POINT INTAKE/DOSE CALCULATIONS

EPCs of chemicals in the various media are used to estimate the potential human intake of those chemicals via each exposure pathway Intakes are expressed in terms of milligrams of chemical ingested, inhaled, or dermally absorbed, per kilogram of body weight per day (mg/kg-day) Intakes are calculated following guidance in RAGS (EPA 1989a) and other EPA guidance documents as appropriate Intakes are estimated using exposure parameters such as body weight, inhalation volume, ingestion rates, soil or food matrix effects, and frequency and duration of exposure

Dose is estimated as a function of how much contaminant enters the body The process of a chemical entering the body occurs in two steps First, an exposure, or contact with the chemical must take place Second, actual entry into the receptor must occur The amount of chemical absorbed by the body (internal dose), after entry into the receptor, will be estimated

The two major processes by which a chemical can cross the boundary from outside to inside the body are intake and uptake Intake involves physically moving the chemical through an opening in the body such as the mouth or nose and usually occurs via inhalation, eating, or drinking The chemical is normally contained in a carrier medium such as air, food, or drink The estimate of how much chemical enters the body focuses on how much of the carrier medium enters The uptake process of a chemical entering the body involves absorption of the chemical through the skin or other exposed tissue such as the eye Although the chemical is normally contained in a medium, the medium typically is not absorbed at the same rate as the chemical Therefore, the estimates of the amount of chemical entering the body are greatly affected by such factors as the concentration gradient across the boundary and permeability of the barrier

The reasonable maximum exposure (RME) is estimated using the 95% UCL EPC concentration and values for exposure variables so that the combination of all variables results in the maximum exposure that can reasonably be expected to occur at the Site (EPA 1992d)

51

The general equation for calculating intake in terms of mg/kg-day is

$$Total\ intake\ (mg/kg\text{-}day) = \frac{C \times IR \times EF \times ED}{BW \times AT} \qquad \text{(Equation 5-1)}$$

where

C	=	concentration (milligrams per volume [mg/vol])
IR	=	intake rate (volume per day [vol/day])
EF	=	exposure frequency (days/years)
ED	=	exposure duration (years)
BW	=	body weight (kilogram [kg])
AT	=	averaging time (days)

For noncarcinogenic chemicals, intakes are calculated by averaging over the period of exposure to yield an average daily intake For carcinogens, intakes are calculated by averaging the total cumulative dose over a lifetime, yielding "lifetime average daily intake" (EPA 1989a) Different averaging times are used for carcinogens and noncarcinogens because their effects occur by different mechanisms (EPA 1989a) The approach for carcinogens is based on the hypothesis that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime, and the intake of a carcinogen is averaged over a 70-year lifetime regardless of exposure duration (EPA 1989a) When Equation 5-1 is used to calculate intakes of radionuclides, the denominator (body weight x averaging time) is excluded from the calculation Intakes of noncarcinogens are averaged over the period of exposure (usually 25 to 30 years), because potential effects would be expected to occur during the period of exposure

Omitting chemical concentrations or dose from the intake equation yields an "intake factor" that is constant for the respective exposure pathway and receptor. The intake factor can then be multiplied by the concentration or dose of each chemical to obtain the pathway and receptor-specific intake of the chemical Intake factors are calculated separately for each applicable exposed receptor and exposure pathway The following are generalized pathway-specific equations in use at RFETS

5.5.1 Ingestion of Water

$$Intake\ (mg/kg\text{-}day) = \frac{CW \times IR \times EF \times ED}{BW \times AT} \qquad \text{(Equation 5-2)}$$

where

CW	=	chemical concentration in water (milligrams per liter [mg/L])
IR	=	ingestion rate (Liters per day [L/day])
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged, days)

52

For calculation of radionuclide intakes, the exposure concentration is expressed in (pCi/L), and the expression is not divided by body weight and averaging time The resulting intake for radionuclides is expressed in pCi This rule applies to all of the following equations

5.5.2 Dermal Contact With Water

The equation used for dermal contact with contaminants in water is presented below This equation calculates the actual absorbed dose (i e , intake, not the amount of chemical that comes in contact with the skin

$$Absorbed\ dose\ (mg/kg\text{-}day) = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT} \qquad \text{(Equation 5-3)}$$

where

CW = Chemical concentration in water (mg/L)
SA = Skin surface area available for contact (cm^2)
PC = Chemical-specific dermal permeability constant (cm/hour)
ET = Exposure time (hours/days)
EF = Exposure frequency (days/years)
ED = Exposure duration (years)
CF = Volumetric conversion factor for water (1 liter per 1,000 cubic centimeters [1 L/1000 cm^3])
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged, days)

5.5.3 Inhalation of Airborne Contaminants

Airborne contaminants may be either in the vapor phase or, in the case of metals and radionuclides, in particulate form Dermal absorption of vapor-phase contaminants is considered to be negligible in proportion to inhalation intakes and, therefore, is disregarded in accordance with RAGS (EPA 1989a) The following equation is used

$$Intake\ (mg/kg\text{-}day) = \frac{CA \times IR \times EF \times ED}{BW \times AT} \qquad \text{(Equation 5-4)}$$

where

CA = contaminant concentration in air (milligrams per cubic meter [mg/m^3])
IR = inhalation rate (cubic meters per day [m^3/day])
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged - days)

Only the fraction of the particulate concentration in air considered to be respirable (<10 microns [μm]) is evaluated for calculation of intakes from inhalation of particulates The respiratory model developed by the International Commission on Radiological Protection

53

indicates particles above 10 μm are relatively unimportant contributors to internal dose (NCRP 1985)

5.5.4 Incidental Ingestion of Soil or Sediments

The following equation is used in calculating the intake from incidental ingestion of contaminants in soil or sediments

$$Intake\,(mg/kg\text{-}day) = \frac{CS \times IR \times CF \times FI \times EF \times ED}{BW \times AT} \qquad \text{(Equation 5-5)}$$

where

CS = chemical concentrations in soil (mg/kg)
IR = ingestion rate (milligrams [mg] soil/day)
CF = conversion factor (10^{-6} kilograms per milligram [kg/mg])
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (days/years)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged, days)

5.5.5 Dermal Contact With Soil or Sediments

The exposure from dermal contact with contaminants in soil and sediments is calculated using the following equation, which results in an estimate of the absorbed dose, not the amount of chemical in contact with the skin (i e , intake)

$$Absorbed\ Dose\,(mg/kg\text{-}day) = \frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT} \qquad \text{(Equation 5-6)}$$

where

CS = chemical concentration in soil or sediments (mg/kg)
CF = conversion factor (10^{-6} kg/mg)
SA = skin surface area available for contact (cm^2/event)
AF = soil to skin adherence factor (milligrams per square centimeter[mg/cm^2])
ABS = absorption factor (unitless)
EF = exposure frequency (events/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged, days)

5.5.6 Ingestion of Garden Fruits and Vegetables

The contaminant intakes for ingestion of garden produce are calculated using the following equation

54

$$Intake\,(mg/kg\text{-}day) = \frac{CF \times IR \times FI \times EF \times ED}{BW \times AT} \qquad \text{(Equation 5-7)}$$

where

CF = contaminant concentration in food (mg/kg)
IR = ingestion rate (kg/day)
FI = fraction ingested from contaminated source (unitless)
EF = exposure frequency (days/year)
ED = exposure duration (years)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged, days)

5.5.7 External Radiation Exposure

Radionuclide intakes for external exposure are calculated using the following equation

$$Intake\,(pCi) = C \times ED \times (1 - Se) \times Te \qquad \text{(Equation 5-8)}$$

where

C = isotope activity (picocuries per gram [pCi/g])
ED = exposure duration (years)
Se = gamma shielding factor (unitless)
Te = gamma exposure factor (unitless)

55

6.0 HUMAN HEALTH RISK CHARACTERIZATION PERFORMED ON AN EXPOSURE UNIT AND SITEWIDE BASIS

Concluding the HHRA process is a six step characterization process

1 Results of the toxicity and exposure assessments (Sections 4 0 and 5 0) for the COCs under study are checked and integrated

2 The potential risks to public health, both carcinogenic (total cancer risk) and noncarcinogenic (hazard quotients [HQs] and HIs), are quantified for each substance and pathway identified in the exposure assessment

3 Risks and HIs are summed across pathways where appropriate

4 Uncertainty of the estimates is assessed and discussed

5 The results of any Site-specific exposure studies are discussed in relation to the risk assessment results

6 The results of the CRA are summarized and discussed in relation to the final Site remedy

In general, during the risk characterization process, the RME chemical-specific intakes calculated in the exposure assessment are multiplied by the applicable chemical-specific dose-response factors to compute estimates of the cancer risk for an individual over a lifetime of exposure, or compared with the appropriate RfD, (chronic, subchronic, or acute), for noncarcinogenic health effects The nature, weight-of-evidence, and magnitude of uncertainty for the potential critical health effects are considered The process of quantifying health risks includes the following

- Calculating and characterizing carcinogenic effects for each substance, pathway, and exposure scenario,
- Calculating and characterizing noncarcinogenic effects for each substance, pathway, and exposure scenario,
- Calculating and characterizing radiation dose for each radionuclide, pathway, and exposure scenario, and
- Conducting qualitative (or quantitative, when possible) uncertainty analysis

Each of these is discussed in the following sections

6.1 CALCULATING AND CHARACTERIZING CARCINOGENIC EFFECTS

The following calculations will be used to determine carcinogenic effects by obtaining numerical estimates (i e , unitless probability) of lifetime cancer risks

$$Risk = Intake \times CSF \quad \text{(Equation 6-1)}$$

where

Risk = potential lifetime excess cancer risk (unitless probability)

56

CSF = cancer slope factor $(mg/kg\text{-}day)^{-1}$ or $(pCi)^{-1}$

Intake = chronic daily lifetime intake (mg/kg-day) or (pCi)

CSFs will be used as provided in the IRIS (EPA 2000a) Inhalation and oral ingestion CSFs are used with respective inhalation and ingestion intakes to estimate potential carcinogenic health risks The CSFs used are presented and discussed in the toxicity assessment (Section 4 1) The above equation assumes a linear relationship in the low-dose portion of the dose-response model The slope factor is usually the upper 95th percentile confidence limit on the probability of response, based on animal data, resulting in upper-bound risk estimates

Cancer risks are summed separately across all potential chemical carcinogens and radionuclides considered in the risk assessment using the following equation

$$Risk_T = \Sigma Risk_i \qquad \text{(Equation 6-2)}$$

where

$Risk_T$ = total cancer risk (a unitless probability)

$Risk_i$ = risk estimate for the i^{th} contaminant (unitless probably)

This equation is an approximation of the precise equation for combining risks to account for the probability of the same individual developing cancer as a consequence of exposure to two or more carcinogens The difference between the precise equation and this approximation is negligible for total cancer risks less than 0 1 (EPA 1989a) The risk summation assumes independence of action by the compounds (i e , no synergistic or antagonistic actions). The limitations of this approach include conservative risk estimates due to the use of multiple upper-bound estimates of CSFs, increased uncertainty when adding potential carcinogenic risk across weight-of-evidence cancer classes (A through C), and uncertainty due to possible interactions among carcinogens

A table of risks for each exposure scenario will be created to show contaminant- and pathway-specific risk, with contaminants presented by rows and pathways presented by columns Reasonable exposure pathway combinations will be identified and the likelihood that the same individuals would consistently be exposed by more than one pathway will be evaluated In most situations, a receptor could be exposed by several pathways in combination For these situations, risks will be subtotaled across pathways for each contaminant

A total carcinogenic risk will also be summed across weight-of-evidence classifications as an aid in the discussion of the uncertainty of the estimates In accordance with EPA guidance, only one significant digit is retained when summarizing calculated risks (EPA 1989) Table 6 1 provides an example table for documentation of carcinogenic risks for a particular exposure scenario

The CRA will discuss risks that exceed the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) risk range of 10^{-4} to 10^{-6} (EPA 1990) Specifically, the pathways and contaminants driving the risk will be noted and accompanied by a discussion of any qualifying information

In addition to presenting the incremental cancer risks due to contaminants at the Site, perspective may be provided by giving examples of typical background sources of risk such as for arsenic or uranium The text will note assumptions associated with the calculations, and discuss the importance of background risks associated with each exposure scenario The CRA summary section will present risks for each scenario, as well as a brief discussion of the uncertainty of the risk estimates

Table 6-1 RME Carcinogenic Risk for Exposure Scenario X

Chemical	Wt. of Evidence	Pathway 1	Pathway 2	Pathway 3	Pathway n	Scenario Total
Nonradionuclides						
COC 1	A	#	#	#	#	#
COC 2	A	#	#	#	#	#
COC 3	#	#	#	#	#	#
COC n	#	#	#	#	#	#
Wt. of Evidence Total	#	#	#	#	#	#
Pathway Total		#	#	#	#	#
Total Risk						#
Radionuclides						
Rad COC 1	A	#	#	#	#	#
Rad COC 2	A	#	#	#	#	#
Pathway Total		#	#	#	#	
Total Risk						#

6.2 CALCULATING AND CHARACTERIZING NONCARCINOGENIC EFFECTS

Health risks associated with exposure to individual noncarcinogenic compounds are determined by calculating HQs and HIs The noncarcinogenic HQ is the ratio of the intake or exposure level to the RfD, as follows

$$HQ_i = Intake_i/RfD_i \qquad \text{(Equation 6-3)}$$

where

HQ_i = noncarcinogenic HQ for i^{th} substance

$Intake_i$ = intake for i^{th} substance (mg/kg-day) for appropriate exposure period

RfD_i = reference dose for i^{th} substance(mg/kg-day) for appropriate exposure duration

Inhalation and oral ingestion RfDs are used with respective inhalation and ingestion intakes to estimate potential noncarcinogenic health effects Intake and RfD are expressed in the same units and represent the same exposure period The RfDs used are presented and discussed in the toxicity assessment of the CRA COCs that have been determined to have subchronic (2-week to 7-year exposure) or acute (less than 2-week exposure) effects in the

58

toxicity assessment will be characterized using subchronic or acute RfDs, or other dose-response information, as available

HIs are the summed HQs for each chemical across an exposure pathway An HI is calculated using the following equation

$$HI_{pw} = \sum HQ_i \qquad \text{(Equation 6-4)}$$

where

HI_{pw} = HI index for an exposure pathway

HQi = HQ for the i^{th} COC

The HI_{pw} values are not statistical probabilities of a potential effect If the HI_{pw} exceeds unity, there is a concern for potential noncarcinogenic health effects In general, the greater the HI above unity, the greater the level of concern However, the level of concern does not increase linearly as the HI approaches or exceeds unity Further discussions and limitations on the application of this procedure are presented in RAGS (EPA 1989a)

Noncarcinogenic effects will be presented in the CRA tables similar to those used in the presentation of carcinogenic risk Each table will show contaminant and pathway-specific effects with contaminants presented in rows, and pathways presented by columns HI_{pw}s will be subtotaled across pathways to develop an HI for the exposure scenario (HI_{cs}), if the same individuals would consistently be exposed to more than one pathway for each contaminant

HQ_is approaching or exceeding 1 will be segregated and summed by mode of action or target organ to calculate the total HI by target organ (HI_{to}) A total HI_{to} may also be summed across all pathways and contaminants for a specific receptor scenario. Both of these procedures are subject to limitations (EPA 1989a) In accordance with the convention with carcinogenic risk, only one significant digit is retained when summarizing the calculated indices Table 6-2 provides an example table for presentation of HIs

The CRA will discuss Hazard Quotients (HQs) and HIs that exceed unity The pathways and contaminants driving the risk will be noted and discussed A summary table presenting HI_{cs} subtotals for all scenarios will be created for presentation in the CRA risk summary section This may be presented by placing the results for each scenario in rows, and providing information on HIs, dominant COCs, and dominant pathways in columns.

Table 6-2 RME Noncarcinogenic Hazard Indices for Exposure Scenario X

Chemical	Pathway 1	Pathway 2	Pathway 3	Pathway n	Scenario Total
COC 1	#	#	#	#	#
COC 2	#	#	#	#	#
COC 3	#	#	#	#	#
COC n	#	#	#	#	#
Pathway Total	#	#	#	#	
Total HI					#

6.3 CALCULATING AND CHARACTERIZING RADIATION DOSE

The following calculations will be used to determine the radiation dose

$$Dose = Intake \times DCF \qquad \text{(Equation 6-5)}$$

where

DCF = dose conversion factor factor (millirems per picocurie [mrem/pCi]) or (millirems per picocurie per gram [mrem/pCi/g])
Intake = radionuclide intake or media concentration (pCi) or (pCi/gram)

Inhalation and oral ingestion DCFs are used with respective inhalation and ingestion intakes to estimate radiation dose For external irradiation, external DCFs are used with respective soil concentrations to estimate radiation dose DCFs are calculated using mathematical extrapolation models based on human epidemiological studies

Radiation dose is summed separately across all potential radionuclides considered in the dose assessment using the following equation

$$Dose_T = \Sigma Dose_i \qquad \text{(Equation 6-6)}$$

where

$Dose_T$ = total radiation dose, expressed in mrem

$Dose_i$ = radiation dose estimate for the i^{th} radionuclide

A table of radiation doses for each exposure scenario will be created to show contaminant- and pathway-specific dose, with radionuclides presented by rows and pathways presented by columns (Table 6-3) Reasonable exposure pathway combinations will be identified and the likelihood that the same individuals would consistently be exposed by more than one pathway will be evaluated In most situations, a receptor could be exposed by several pathways in combination. For these situations, dose will be subtotaled across pathways for each radionuclide

In addition to presenting the incremental radiation dose due to radionuclides at the Site, perspective may be provided by giving examples of typical background sources of dose from anthropogenic and terrestrial sources Assumptions associated with the calculations will be noted and discussed The CRA summary section will present doses for each exposure scenario and present a brief discussion of the uncertainty of the risk estimates.

Table 6-3 RME Radiation Dose for Exposure Scenario X

Radionuclide	Pathway 1	Pathway 2	Pathway 3	Pathway n	Scenario Total
COC 1	#	#	#	#	#
COC 2	#	#	#	#	#
COC 3	#	#	#	#	#
COC n	#	#	#	#	#
Pathway Total	#	#	#	#	#
Total Dose					#

6.4 CONDUCTING QUALITATIVE UNCERTAINTY ANALYSIS

The quantification of uncertainty is an important component of the risk assessment process According to the EPA *Guidance on Risk Characterization for Risk Managers and Risk Assessors* (EPA, 1992c), point estimates of risk "do not fully convey the range of information considered and used in developing the assessment " To provide information about the uncertainties associated with the RME estimate, uncertainties identified during the CRA process and presented in qualitative and, where appropriate, quantitative terms

There are four stages of analysis applied in the risk assessment process that can introduce uncertainties

- Data collection and evaluation,
- Exposure assessment,
- Toxicity assessment, and
- Risk characterization

The uncertainty analysis characterizes the various sources and their contributions to uncertainty in the CRA These uncertainties are driven by uncertainty in the site investigation data, likelihood of hypothetical exposure scenarios, transport modes used to estimate concentrations at receptor locations, receptor intake parameters, and toxicity values used to characterize risk Additionally, uncertainties are introduced in the risk assessment when exposures to several substances across multiple pathways are summed.

The concept of uncertainty can be more fully defined by distinguishing between variability and knowledge uncertainty Variable parameters are those that reflect heterogeneity in a well-characterized population, for which the distributions would not generally be narrowed through further measurement or study Certain parameters reflect a lack of information about properties that are invariant and whose single, true value could be known exactly by the use of a perfect measuring device Where appropriate, qualitative uncertainty analysis may distinguish between variability and uncertainty. Qualitative uncertainty analysis will identify each key source of uncertainty, present an estimate of the relative impact of the uncertainty on the CRA, and include any clarifying remarks.

6.5 CONDUCTING QUANTITATIVE UNCERTAINTY ANALYSIS

In some cases, quantitative uncertainty analysis may be conducted in addition to the qualitative uncertainty analysis Quantitative uncertainty analysis will be performed on chemicals and/or sets of chemicals that have a carcinogenic risk greater than 1×10^{-4} or a noncarcinogenic HQ or HI greater than 1 To quantify the uncertainty in the final risk characterization estimates, Monte Carlo simulations may be used for the pathways dominating the risk (EPA 1997b) Because of the conservative assumptions built into the risk assessment process, Monte Carlo simulations are considered to be adequately conservative

The Monte Carlo simulation is a technique that can be used to provide a probability function of estimated risk using random values of exposure factors and toxicity values in an exposure scenario A Monte Carlo simulation involves assigning a joint probability distribution to the input variables (i e , exposure factors) of an exposure scenario Next, a large number of independent samples from the assigned joint distribution are taken and the corresponding outputs calculated This entails repeated computer iterations assigning random number values to the exposure factors The simulated output represents a sample from the true output distribution Methods of statistical inference are used to estimate key parameters of the output distribution (e g , percentiles) from the output sample

The risk distributions produced by Monte Carlo simulations present significantly more information than do point estimates However, the level of effort involved in conducting a quantitative uncertainty analysis must be weighted against the importance of this information to risk managers No decision has been made to date by the involved parties on the use of Monte Carlo methods in the RFETS CRA

62

7.0 ECOLOGICAL RISK ASSESSMENT

7.1 INTRODUCTION

This section provides an approach for performing the Ecological Risk Assessment (ERA) portion of the CRA for RFETS The approach amends previous RFETS Ecological Risk Assessment Methodology (ERAM) (DOE 1996c, 1996d) with more recent EPA guidance on performing ERAs at Superfund sites (EPA 1997c, 1999b, 2000b) The RFETS ERAM was used in performing risk assessments for the RFI/RIs, for IHSSs and other source areas in the Woman and Walnut Creek watersheds The results of these ERAs presented in the *Draft Final Phase I RFI/RI Report Appendix N, Woman Creek Priority Drainage Operable Unit No 5* (DOE 1995b) An ERA has not been performed for source areas within the IA

Human health and environmental risk within the IA will be evaluated and addressed using risk-based remediation approach described in RFCA The overall RFCA approach involves comparison of risk-based ALs to Site data to determine whether chemical contaminant concentrations in a given area of the Site exceed acceptable risk from exposure to environmental contaminants ALs developed for RFCA were based on protection of human health The RFETS ERAM currently includes methods for calculating overall exposure of receptors through multiple pathways, and dose-based toxicity reference values (TRVs) to assess the toxicity of estimated exposures However, the ERAM does not include values expressed as concentrations that can be directly compared to environmental data The ERAM is modified in this document to include a process for developing screening values for comparison to COCs.

In addition, the ERAM is being modified to make it more consistent with the recent EPA *Ecological Risk Assessment for Superfund Process for Designing and Conducting Ecological Risk Assessments* (Interim Final) (1997c) This EPA guidance includes eight steps to perform an ERA They are as follows

1 Preliminary Problem Formulation and Ecological Effects Evaluation,
2 Screening-Level Exposure Estimate and Risk Calculation,
3 Baseline Risk Assessment Problem Formulation,
4 Study Design and Data Quality Objective Process,
5 Field Verification of Sampling Design,
6 Site Investigation,
7 Risk Characterization, and
8 Risk Management

Steps 1 and 2 comprise the Screening-Level Ecological Risk Assessment (SLERA), the results of which are used to determine whether further data collection and/or risk analysis is necessary The screening-level analysis may consist of quantitative or qualitative analyses and professional judgement of the risk assessors and risk managers At the end of Step 2, the process includes a Scientific Management Decision Point (SMDP) in which risk managers

make the decision whether to proceed with further data collection or analyses to support additional risk assessment or remediation planning

If the need for further risk analyses is indicated at the end of Step 2, planning for analyses and any additional data collection are conducted in Step 3, a sampling and analysis plan (SAP) is prepared in Step 4, and the plan is implemented in Steps 5, 6, and 7

The ERAM is modified in this document to include methods for development of soil screening values (SSVs) for use in the SLERA portion of the EPA process SSVs will be developed for COCs anticipated to be more restrictive than RCFA ALs The SSVs can be used to assess risks in association with the IA investigations, as well as other ecological risk-based screening activities that may be required for the CRA

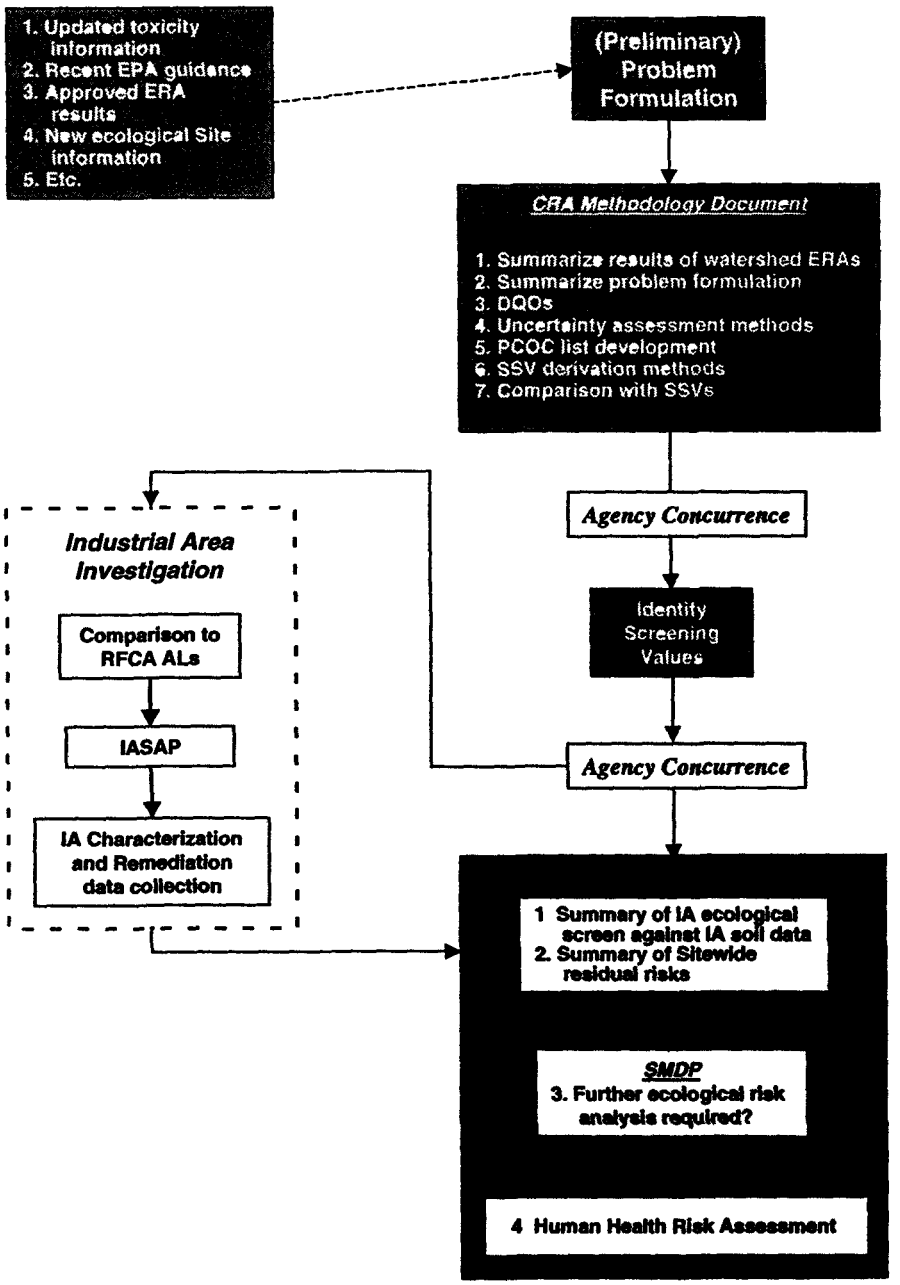
The SMDP at the end of the SLERA largely depends on the uncertainty about whether remediation is necessary to attenuate ecological risk at the site The SLERA will be performed using available data on contaminant concentrations, exposure parameters, and knowledge of ecological effects To date, the ERA process at RFETS has included extensive characterization of risks in the BZ and contaminant source areas outside the IA This included preparation of a comprehensive exposure and risk analyses for the BZ in the Watershed ERAs (DOE 1995c) Results of the watershed ERAs indicated negligible ecological risks throughout most of the BZ Relatively low risks were associated with some of the sediment retention ponds Uncertainties in the overall analysis were identified

Thus, the results of the watershed ERAs provide extensive information for determining the scope of evaluations that should be included in the SLERA for the ERA It is anticipated that risk evaluations for the ERA will be limited to evaluations of how risks associated with pond sediments should be managed, and evaluating residual risks after various remediation activities in the BZ and IA In addition, the ERA may include specific evaluation of the status of risks to the Preble's meadow jumping mouse (PMJM) and its habitat within the BZ.

Information in the following sections provides the basis for the Preliminary Problem Formulation and Ecological Effects Evaluation (Step 1) and the Screening-Level Exposure Estimate and Risk Calculation (Step 2) associated with the SLERA for the IA The sequence of activities for the ERA portion of the CRA are described in Figure 7-1

Based on the information presented in the watershed ERAs, a relatively small amount of uncertainty is associated with risks in the BZ. Greater uncertainty is associated with the IA because an ERA has not been completed for this area. As noted above, ecological risk-based screening values will be initially developed for selected COCs so that data collected for the IA can be simultaneously evaluated for ecological and human health risks. This approach is similar to development of preliminary remediation goals (PRGs) for HHRAs (EPA 1991) (Figure 7-1)

Figure 7-1 Sequence of Activities for Ecological Risk Assessment Portion of the Comprehensive Risk Assessment



This document provides a methodology for development and use of screening values in the IA or other areas that may require risk analysis in the future As part of the Preliminary Problem Formulation for the ERA, results of the previous watershed ERAs are summarized in Section 7 2 An approach for conducting the SLERA for the IA is presented in Section 7 9 The supporting information such as problem formulation, DQOs, data sufficiency, sources of uncertainty, and PCOC development is described in Sections 7.3 through 7.8

65

7.2 REVIEW AND SUMMARY OF WATERSHED ERAS

7.2.1 WATERSHED ERA METHODOLOGY

This section presents the methods and results for the ERAs conducted for the Walnut Creek and Woman Creek watersheds (DOE 1995b) These watershed ERAs represented the ecological portions of the baseline risk assessments associated with the RCRA RFI/RIs for OUs 1, 2, 4 (in part), 5, 6, 7, 10 (in part), and 11 The combined watershed ERAs were conducted based on agreements among EPA, CDPHE, and the U S Department of Energy (DOE) ERAs were formerly planned for each OU, and preliminary field investigations were conducted on that basis The regulatory agencies agreed that it was more appropriate to conduct the ERAs for each watershed, because the watershed scale is more relevant to ecological receptors than administrative boundaries

The ERAM for RFETS (DOE 1996c, 1996d) was originally developed to support risk management decisions for individual OUs The approach used was consistent with a screening-level risk assessment appropriate for sites where ecological effects have not been observed, but contaminant levels have been measured and can be compared with concentrations considered protective of ecological receptors

The RFETS ERAM drew information from DOE and EPA guidance and ERA tools developed at Oak Ridge National Laboratory (ORNL) (Efroymson et al , 1997) and the Savannah River Site (DOE 1993b, 1993c, EPA 1992d, 1994c, 1997c, Norton et al. 1992, Opresko et al 1994) The watershed ERAs included three phases identified in EPA guidance (1) preliminary risk calculations and problem formulation, (2) analysis, and (3) risk characterization

Site Conceptual Model for Watershed ERAs

Development of the Sitewide Conceptual Model (SCM) was the first step in the problem formulation phase of ERAs conducted for RFETs The purpose of the SCM is to help identify environmental stressors and the potential pathways by which ecological receptors may be exposed to them This step allows investigators to identify the potentially complete pathways that will become the focus of the ERA The SCM also aids in the selection of measurement endpoints for use in evaluation of assessment endpoints (Suter 1993)

The SCM for the watershed ERAs was described and approved during the Technical Memoranda (TM) process The Sitewide Conceptual Model Technical Memoranda (SCMTM) (DOE 1996c, DOE 1996d) established the relationship between the key components of the RFETS ecosystem The following information was included in the SCMTM

- Description of the environmental setting at RFETS, including the natural physical and biological systems and a brief description of the primary contaminant source areas or IHSSs,
- Description of the important contaminant fate and transport pathways in abiotic media,

66

- Description of the important exposure pathways (Figure 7-2), including primary exposure media, exposure points, receptor guilds, and exposure routes,
- Description of receptor guilds and identification of key species in each guild to be used in representative exposure estimates at RFETS,
- Species-specific exposure parameters to be used in estimating exposure to key receptors,
- Measurement endpoints for which data have been collected

The SCMTM (DOE 1996c, 1996d) also summarized existing environmental data, data sources, and ongoing monitoring programs

7.2.2 Watershed ERA Data

As noted above, preliminary field investigations were performed for each OU prior to the integration of ERAs into watersheds The watershed ERAs focused primarily on estimation of exposure from available data on contaminant distribution in abiotic and biotic media. A large and comprehensive database of RFI/RI data was available for evaluating contaminant distribution in abiotic media In addition, biological tissue samples from each OU were analyzed for metals and radionuclides, and these data were used to document exposures

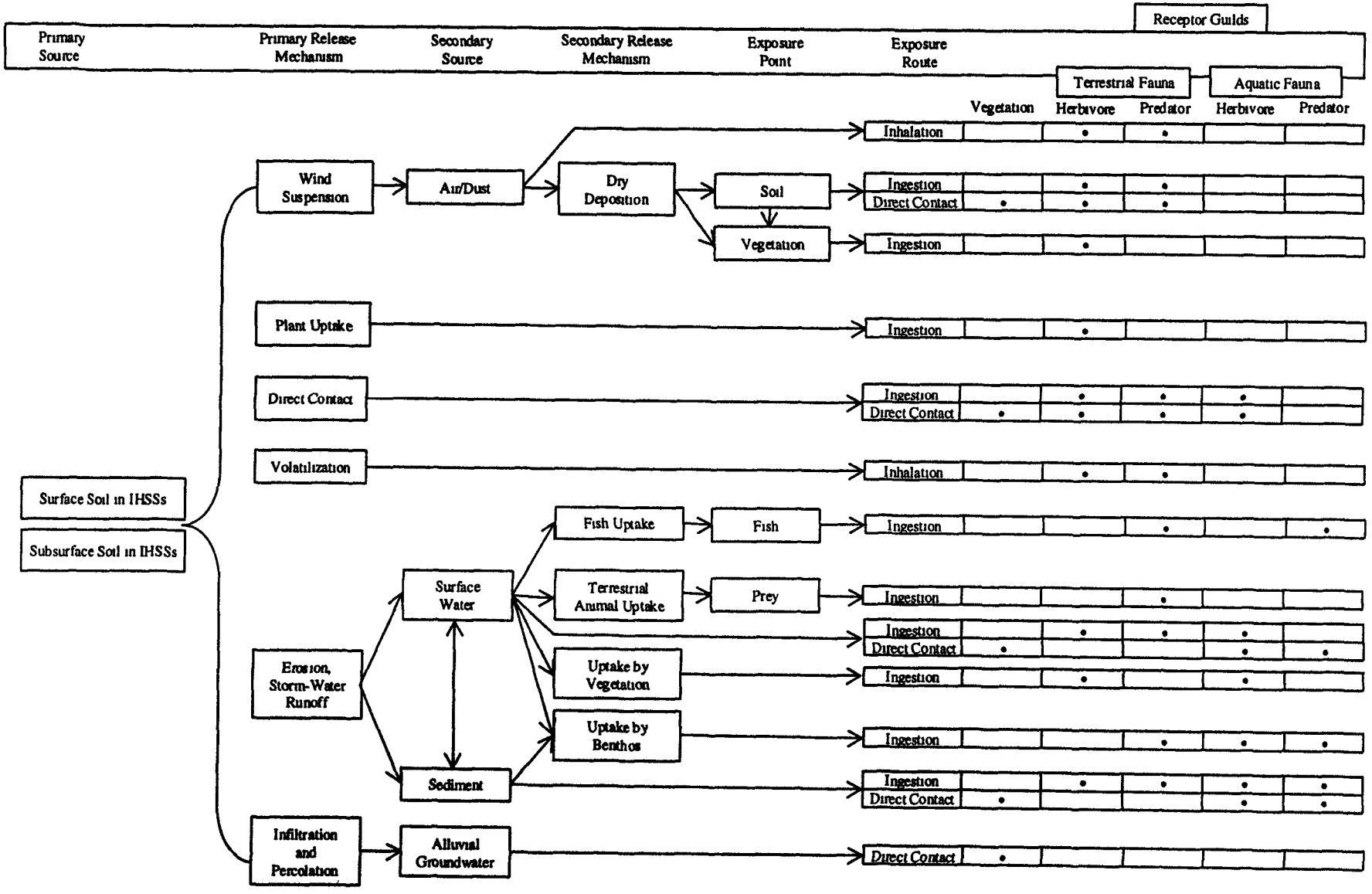
7.2.3 ECOC and Benchmark Methodology

The ecological chemical of concern (ECOC) Screening Methodology TM (DOE 1996c) describes the methodology to identify ECOCs for use in the RFETS ERAs Data on chemical distribution in biotic and abiotic media associated with potential contaminant source areas (IHSSs) were screened using ECOC screening methodology based on a three-tiered approach The three-tiered PCOC selection process should not be confused with the Tier I and Tier II soil action levels established in RFCA (DOE 1996a) The first tier was intended to identify site-specific contaminants for each ERA The evaluation included statistical analyses and professional judgement and resulted in a list of PCOCs that was then used to determine the COCs for the ERA

The potential ecotoxicity of PCOCs was evaluated in the second and third tiers. Evaluations were conducted only for complete exposure pathways. The second and third tier screens each required estimates for exposure of representative or key receptors site contaminants. Representative species of birds, small mammals, large mammals, and fish were selected based on their abundance at RFETS, special legal status, and position in local food webs Information on life history, body size, diet, and other parameters needed to estimate exposure were also presented in the SCMTM

67

Figure 7-2 Ecological Exposure Pathway



68

First Tier Screen - PCOC Selection
The potential toxicity of exposures to PCOCs was assessed in the watershed ERAs This information was then used to identify chemicals (ECOCs) for which exposure analysis was conducted A preliminary risk screen was performed for more than 150 PCOCs to identify those that were present at potentially ecotoxic concentrations Screening-level assumptions were adopted to minimize the chance of underestimating risk from a given PCOC The result of the preliminary risk screen was a list of potential ECOCs, for which potential risk was identified

Second Tier Screen - ECOC Selection
The Tier 2 screen was equivalent to preliminary exposure and risk calculations included in Step 2 of the most recent EPA ERA guidance (1994c, 1997c) The Tier 2 screen provided an efficient and conservative mechanism to identify Tier 1 potential ECOCs that are/were present at potentially ecotoxic concentrations Estimation of exposure and comparison to benchmarks for this tier involved a limited number of species The screen was conservative because it assumed that receptors are continuously exposed to the highest concentrations detected The screen also evaluated potential toxicity to individuals instead of effects to populations or communities

Third Tier Screen - Risk Characterization
ECOCs identified in Tier 2 were carried into Tier 3. Tier 3 was also considered a screening step However, it included a more accurate method for estimating exposure than Tier 2 because it incorporated the distribution of chemicals in the environment and spatial and temporal aspects of receptor behavior Factors such as diet, home-range size, seasonal migration, and body size affect the frequency, duration, and intensity of contact with contaminated media Adjustment of exposure parameters in Tier 3 to account for these factors is important in obtaining more objective estimates

Potential ecotoxicity of contaminants was evaluated by comparing site-specific exposures to ecotoxicological benchmarks developed for various receptor species from established databases or scientific literature The comparison was expressed as an HQ or the ratio of a site-specific exposure estimate to the benchmark (EPA 1994c)

The potential risk from exposure to ECOCs was further characterized for key receptor groups The approach and methods for risk characterization were described in a problem formulation step designed to be consistent with EPA guidance on conducting ERAs (EPA 1994c) However, in contrast with EPA guidance, risk characterization was performed using existing data and toxicity information Data were available on concentrations of metals, radionuclides, and certain organic chemicals (pesticides and polychlorinated biphenyls [PCBs]) in aquatic and terrestrial biota in each OU These data were reliable indicators of exposure and were collected to evaluate exposure of upper level consumers to chemicals accumulated in forage or prey (Suter 1993)

Benchmarks
Benchmarks are usually selected so that significant ecological effects are not expected when exposures are lower than the benchmarks (e g , HQ < 1) Concentrations or exposures exceeding benchmarks (e g , HQ >1) do not necessarily indicate significant risk, but do indicate the contaminant should be further evaluated

Ecotoxicological benchmarks values for the watershed ERAs were based on a database developed at ORNL (ORNL 1994) In most cases, benchmarks were derived from data on the toxicity to laboratory test animals and extrapolated to wildlife species by scaling to body size and applying uncertainty factors to account for variability among species and data types (ORNL 1994) The ORNL method was used to develop benchmarks for key receptor species at RFETS

7.2.4 Watershed Results Summary

The results for the previous work conducted in the BZ are summarized by watershed, receptor group, ECOC, and ERA source areas in Tables 7-1 and 7-2. More specific results can be found in DOE (1995b).

Summary of Risks to Aquatic Life
The screen identified several ECOCs in sediments but none for surface water Sediment ECOCs included VOCs, semivolatile organic compounds (SVOCs), PCBs, and metals

The magnitude of sediment HQ and HI values for some sites in Walnut Creek suggested a high level of toxicity to benthic organisms, especially in the A- and B-series ponds farthest upstream and closest to the IA HQs exceeded 100 for some chemicals at these sites Polynuclear aromatic hydrocarbons (PAHs) were the main contributors to risk estimates at most sites in Walnut Creek, accounting for 90 percent or more of the HI in Ponds A-1 and B-1 Risk estimates were much lower in the Woman Creek watershed where HIs were below 3, no HQ exceeded 2 6. PAHs were also the main contributors to risk estimates in Woman Creek

The risk levels predicted by the HQ and HI calculations were verified using results of sediment toxicity tests and site data on benthic community structure The results suggested that although toxicity tests do not show robust toxicity, effects of sediment contamination may be manifested in the benthic community structure of the detention ponds However, other factors such as size, fluctuating water levels, and the presence or absence of upper trophic levels are also important Potential toxicity of sediment contaminants, particularly PAHs, may be important factors in limiting aquatic communities if physical stress was reduced through a change in management of the ponds

Summary of Risks to Aquatic-Feeding Birds
ECOCs identified for aquatic-feeding wildlife included PCBs (Aroclor-1254), di-n-butyl-phthalate (DBP), and mercury Great blue herons and mallards were identified as representative receptors because birds are more sensitive to many contaminants than mammals

Aroclor-1254 was detected in sediments of the A- and B-series ponds with the highest concentrations in Ponds B-1 and B-2. Available data on PCB content of aquatic biota indicated negligible levels for birds feeding on fish, amphibians, or invertebrates from the ponds. However, biological tissue data were not available to evaluate the potential risk from

Table 7-1 Summary of Ecological Risks for Walnut Creek Watershed

Receptor Group	ECOCs	ERA Source Area	Media/Exposure Point	Conclusions
Wide-Ranging Wildlife	None	Not Applicable	Not Applicable	The Tier 3 ECOC screen did not identify ECOCs
Aquatic Life	Metals and Organics in Sediments	OU 6 A-Ponds OU 6 B-Ponds	Sediments	Risks are primarily due to PAHs in sediments However, no toxicity was detected in sediment toxicity tests with *Hyalella azteca* Importance of sediment contamination is unclear but does not appear to be the to be the primary factor controlling benthic community structure
Aquatic-Feeding Birds	Aroclor-1254	OU 6 A-Ponds OU 6 B-Ponds	Pond Sediments	Aroclor-1254 concentrations in sediment exceeded risk-based criteria for Ponds B-1, B-2, and B-3 only if top aquatic predators were present Ponds currently do not support this type of community
	Mercury	OU 6 A-Ponds OU 6 B-Ponds	Fish Tissue	Mercury was detected in 75% of fish from B-ponds However the maximum concentration was detected in B-5, which has the lowest contaminant content The maximum HQ was 2 Mercury does not appear to represent risk to herons
	Di-N-butyl phthalate	OU 6 A-Ponds OU 6 B-Ponds	Sediments	All samples with detectable DBP concentrations were "J" qualified Only one sample corresponds to an HQ of 2, all other HQs are ≤ 1 DBP does not appear to represent risk to herons or mallards
Terrestrial-Feeding Raptors	Chromium	OU 2 903 Pad OU 2 East Trenches	Terrestrial Arthropods	Mean chromium concentration in soil was not greater than the background mean No clear contaminant source exists Chromium is not a risk to the kestrel population at RFETS
	Chromium, Lead	OU 4 Downgradient OU 6 A-Ponds OU 6 B-Ponds	Small Mammals	Chromium and lead were elevated in small mammals from pond areas The source is unclear because soil and sediments contain low levels Risks are possible to individual birds feeding in the area, but effects to RFETS population are minimal
	Mercury, Vanadium	OU 4 Downgradient OU 6 A-Ponds OU 6 B-Ponds	Small Mammals	Mercury and vanadium were detected at low frequency and some concentrations were "J" qualified Risks appear to be minimal
Small Mammals	Plutonium-239/240 Americium-241	OU 2 903 Pad OU 2 East Trenches	Soil	Radionuclides do not present significant risk to terrestrial receptors Maximum tissue concentrations do not result in dose rates that exceed the TRV (0 1 rad/day)
	Barium	OU 6 North Spray Field	Vegetation	The barium HQ of 1 05 indicates exposures are very close to the NOAEL Risks to small mammal populations are negligible Some individual jumping mice might be exposed, but adverse effects would be minimal
	Selenium	OU 7 Downgradient	Vegetation	Selenium exposure exists in a small area but includes habitat for jumping mice The source of selenium is not clear Levels in vegetation were twice that of background Possible adverse effects to individuals exist, but population effects were negligible due to the small area
Vegetation	Metals and Organics	Most Source Areas	Soil, Sediments	Nitrates in OU 7 and OU 4, and silver in B-ponds have the highest risk estimates However, ecological risk is unclear because vegetation in these areas does not appear stressed

Table 7-2 Summary of Ecological Risks for Woman Creek Watershed

Receptor Group	ECOCs	ERA Source Area	Media/Exposure Point	Conclusions
Wide-Ranging Wildlife	None	Not Applicable	Not Applicable	The Tier 3 ECOC screen did not identify ECOCs
Aquatic Life	Metals and Organics in Sediments	OU 2 903 Pad OU 5 C-Ponds OU 5 Old Landfill	Sediments	Risks are primarily due to PAHs in sediments However, no toxicity was detected in sediment toxicity tests with *Hyalella azteca* The importance of sediment contamination is unclear but does not appear to be the primary factor controlling benthic community structure
Aquatic-Feeding Birds	Aroclor-1254	OU 5 C-Ponds	Sediments of SID	Aroclor-1254 concentrations in sediment did not exceed risk-based criteria developed for sediment at RFETS
	Mercury	OU 5 Old Landfill OU 5 C-Ponds	Fish Tissue	Mercury was detected in 2 of 24 fish from C-ponds Mercury was not detected in other fish Risks are significant only if birds obtain all food from C-1
	Antimony	OU 5 Old Landfill	Sediments	The screening estimate assumes 100% site use Actual use is much less because the stream supports a small fish population Risks were not significant when adjusted for realistic site use factor
Terrestrial-Feeding Raptors	Chromium	OU 2 903 Pad OU 2 East Trenches	Terrestrial Arthropods	The mean chromium concentration in soil was not greater than background mean No clear contaminant source exists Chromium was not a risk to the kestrel population at RFETS
Small Mammals	Plutonium-239/240 Americium-241	OU 2 903 Pad OU 2 East Trenches	Soil	Radionuclides do not present significant risk to terrestrial receptors Maximum tissue concentrations do not result in dose rates that exceed TRVs (0 1 rad/day)
	Uranium-233/234 Uranium-238	OU 5 Old Landfill	Soil	See text for plutonium and americium conclusions
Vegetation	Metals	Most Source Areas	Soil, Sediments	Soils of Ash Pits contained several metals with HQs >1 The highest HQ (7 9) was for chromium Ecological risk to vegetation communities is minimal because each of the Ash Pits involves relatively small areas 'Sediments of C-ponds contain mercury at concentrations that exceed TRVs for wetland vegetation However, growth of vegetation in littoral zone appears normal

72

all the ponds for which PCBs were detected in sediments Therefore, Site-specific data on uptake of PCBs by aquatic species were used to estimate the maximum concentration in sediments that would ultimately result in exposures of herons and mallards equal to or less than the TRV Estimates were based on the organic carbon content of sediments and calculated for a range of levels of Site use by the birds

Risk estimates also accounted for the effects of food chain length on biomagnification Accumulation of PCBs in upper level consumers is proportional to the length of the food chain through which PCBs are transferred from sediments to top consumers (Rassmussen et al 1990) Calculations were made for two hypothetical food chains (1) one in which a species such as fathead minnows that feed primarily on zooplankton and algae is the primary prey of aquatic-feeding birds, and (2) one in which the main food source is a piscivorous species such as largemouth bass

Results indicated risks to herons or mallards are negligible if they feed on fish or invertebrates from lower trophic levels However, herons may experience toxic exposures if they feed on upper level consumers from Ponds B-1, B-2, or B-3 more than approximately 40 percent of the time The communities in these ponds currently lack the upper trophic levels, but possible future introduction of predaceous fish or other upper level consumers could result in increased exposure to aquatic birds feeding there

Summary of Risks to Terrestrial-Feeding Raptors

Chromium, lead, mercury, and vanadium were detected in terrestrial arthropods from OU 2 and small mammals from OU 4 and OU 6 source areas (OU 4/6 area) at concentrations that could be toxic to raptors feeding extensively in the areas American kestrels were selected to represent raptors because they have relatively small home ranges and are known to breed at RFETS

Preliminary risk estimates indicated chromium, lead, mercury, and vanadium could also present a risk to raptors feeding extensively in the areas around the A- and B-series ponds. Review of data revealed that vanadium and mercury were detected with low frequency and at relatively low concentrations and probably do not represent an ecological risk. However, chromium and mercury concentrations, were consistently elevated in small mammal samples collected from the pond margins The source of the elevated concentrations in small mammals is not clear because neither metal was consistently elevated in soil or dry sediments They were both included in the PCOCs because of samples that exceeded the upper tolerance limit $(UTL)_{99/99}$ for soil and sediments. Few small mammals collected from sites farther from the ponds contained detectable quantities of either metal

Probabilistic exposure estimates indicate kestrels feeding primarily on small mammals in the OU4/6 areas are likely to ingest chromium and lead at rates that exceed background intakes and TRVs These estimates must be considered conservative because they assume kestrels feed only on small mammals, and small mammal samples from the pond areas are probably overrepresented in the data set Further sampling would be required to more accurately evaluate exposures and identify the source of chromium and lead in small mammals

Summary of Risks to Small Mammals

Preliminary risk estimates indicated little risk to small mammals from ingestion of contaminants in RFETS source areas Barium and selenium were identified as ECOCs in the

13

North Spray Field (OU 6) and OU 7 downgradient source areas, respectively Both metals were detected at potentially ecotoxic concentrations in vegetation Risk was evaluated for populations of more common species and individuals of PMJM, a species of special concern at RFETS

The HQ for barium ingestion from the site was 1 05 The TRV for barium was based on concentrations that produced hypertension in laboratory rats (Perry et al 1983 as cited in Opresko et al 1994) The concentration on which the NOAEL was based was the maximum dose in the study and did not affect growth or food or water consumption in experimental animals Therefore, the level of risk associated with exceeding the TRV is unclear. Thus, the barium concentration in vegetation in this source area may produce some adverse effects in individual animals, but the potential for long-term effects on growth or reproduction is unclear, but appears to be minimal

The source of selenium in vegetation from the OU 7 Downgradient area although it is not clear This area was not subject to spray evaporation of water from the landfill pond (DOE 1995c) The vegetation samples from the area may have included selenium accumulators (such as *Astragalus* sp) that are common at RFETS The area represents an insignificant proportion of the total mesic graSSVand habitat at RFETS. However, the source area is located within areas identified as probable habitat for PMJM

The TRV for selenium was based on intakes calculated for background areas of RFETS (0 317 mg/kg/day), because it exceeded the literature-based ecotoxicological benchmark (0 075 mg/kg/day) This suggests small mammals inhabiting RFETS may be adapted to high ambient concentrations of selenium common in semi-arid areas of the Rocky Mountain west. However, intakes from the OU 7 area are more than twice those estimated for background areas and may represent a risk to individuals that spend all of their time there

The presence of PMJM in the OU 7 Downgradient area had not been confirmed. However, confirmed captures have been recorded for areas approximately 2 2 kilometers (km) east in riparian habitat along Walnut Creek. The OU 7 Downgradient area does not include the well-developed riparian vegetation of these other areas, therefore, it is probably not critical habitat for the PMJM However, it is possible that individuals dispersing from currently inhabited areas could contact vegetation and soil in the OU 7 Downgradient area.

Summary of Risks to Vegetation Communities

HQs for several inorganic contaminants and metals exceeded 1 in subsurface soil and sediments in various source areas The highest HQ for soil was due to nitrates in the OU 7 Downgradient area and silver in sediments of the B-ponds The risks associated with the PCOCs are uncertain As noted previously, no obvious areas of vegetation stress were observed during field investigations. It is possible that concentrations for most ECOC metals in soil are within the range tolerated by plant species at RFETS However, the potential phytotoxicity is not known because soil toxicity tests were not conducted during RFI/RIs.

TRVs were not available for most organic soil or sediment PCOCs HQs were well below 1 for organic PCOCs for which TRVs were available However, as with metals, the potential phytotoxicity of most organic PCOCs was not quantified with plant toxicity tests.

Summary of Risks from Radionuclides

Transuranic radionuclides were identified as PCOCs for most OUs The ECOC screen indicated relatively few areas with radionuclide concentrations (activities) in soil that exceeded TRVs Plutonium-239/240 and americium-241 concentrations in soils exceeded TRVs in two locations in the 903 Pad source areas, and uranium-233/234 and uranium-238 concentrations in soil of the Old Landfill exceeded TRVs at two locations Radionuclides were also elevated in vegetation and small mammals collected from ERA source areas

The potential risks from radionuclide uptake by biota were evaluated by calculating the internal radiological dose and comparing it to the TRV The TRV was based on a benchmark value of 0 1 rad/day, which was identified by International Atomic Energy Agency (IAEA) (1992) as protective of biological receptors Results indicated that maximum radionuclide concentrations measured in small mammals resulted in dose rates at least 1,000 times less than the TRV The potential uptake by predators was also evaluated and indicated risks to predators were also not significant Thus, although abiotic media and biota contain elevated concentrations of transuranic radionuclides, risks of adverse effects appear to be negligible

7.3 SCREENING-LEVEL PROBLEM FORMULATION

As stated previously, the methods used to assess risk for the watersheds will be amended to assess risk after remediation for the entire Site Specifically, in the CRA Report, the environmental setting will be revised after remediation, the PCOC list will be amended to incorporate the latest literature information available, and soil screening values (SSVs) will be calculated to compare directly with the PCOC concentration data.

7.3.1 Environmental Setting

The description of the environmental setting at RFETS will be revised in the CRA, including the Site characterization and brief description of the primary contaminant source areas or IHSSs The primary contaminant source areas will have changed after remediation, because of excavation, fill placement, groundwater or surface water remediation, and capping The Site characterization will include a description of the physical characteristics of the Site such as topography, geology, and hydrology, and the types and extent of plant and animal communities present.

After remediation, species diversity, abundance, and habitats may significantly change Therefore, it will be important to consult with the RFETS IMP and the Natural Resource Protection Program to determine the following.

- Extent of wetlands habitat onsite,
- Sensitive/protected plant species habitat (i e., Ute Ladies'-Tresses) onsite,
- PMJM habitat and capture locations onsite,
- Other Protected or Special Status species sightings or habitats on Site (e g , bald eagles, and peregrine falcons), and

15

- Vegetation/habitat types in the IA

Site physical characteristics such as surface water and groundwater flow patterns and final topography are being modeled through the Site-Wide Water Balance and Land Configuration Design Projects Results of these studies will be used in conjunction with data on nature and extent of contamination, selected assessment endpoints, and COC screening methodologies to complete the Problem Formulation phase of the ERA

7.3.2 Site Conceptual Model

The SCM will be amended to reflect the most appropriate ecological receptors. As stated in the SCMTM (DOE 1996d), the purpose of the SCM is to help identify environmental stressors and the potential pathways by which ecological receptors may be exposed to them This step will allow investigators to identify the potentially complete pathways that will become the focus of the ERA The SCM will also aid in the selection of measurement endpoints for use in evaluation of assessment endpoints (Suter 1993)

Specifically, the CRA will update and provide the following.

- Description of the important contaminant fate and transport pathways in abiotic media,
- Description of the important exposure pathways, including primary exposure media, exposure points, receptor guilds, and exposure routes,
- Description of receptor guilds and identification of key species in each guild to be used in representative exposure estimates at RFETS,
- Species-specific exposure parameters to be used in estimating exposure to key receptors, and
- Measurement endpoints for which data have been collected

7.4 DATA QUALITY OBJECTIVES

For consistency with the HHRA process, the approach to the SLERA is presented in the format of DQOs This process should be viewed as parallel to the HHRA PPRG process

7.4.1 DQO Step 1: State the Problem

Environmental investigations at RFETS indicate release of potentially ecotoxic chemicals into the areas surrounding the Site The Site can be divided into two main components IA and BZ The IA includes approximately 350 acres currently occupied by 400 buildings, other structures, roads, and utilities, and is where the bulk of the RFETS mission activity took place between 1951 and 1989 Most of the buildings and associated structures were used for historic processing activity associated with weapons production (DOE 1999b) The IA is surrounded by an Inner BZ (approximately 660 acres) containing support production

14

activities (landfills, ponds, etc) The Outer BZ contains 5,413 acres of undeveloped land composed of mixed grass prairie with ephemeral drainages

To date, ecotoxicological risks have been characterized only for contaminant source areas that occupy portions of the BZ in the Woman Creek and Walnut Creek watersheds

Results of the watershed ERAs (DOE 1995b) indicated minimal or negligible risks for most of the area evaluated Some minimal risks were identified based on PCB exposures in pond sediments, and some potential hot spots of soil contamination These risks were based on risks to individual organisms that may contact contaminated media in the areas in question However, the analyses suggested little or no risk to populations of receptors in the area

The IA was not included in the watershed ERA because environmental investigations in the area had not progressed sufficiently to allow adequate evaluation of ecological or human health risks

RFETS closure activities are conducted in accordance with RFCA, which includes risk-based human health ALs on which future assessment of environmental risk and successful remediation will be based The ALs are expressed as concentrations, and are used for comparison of contaminant concentration data Ecotoxicologically based screening values are being developed to provide a way for contaminant concentration data to be compared against ecological data for potential ecological risks in the IA and in future ERA activities

The problem to be addressed by the CRA ERAM can be expressed as the following objectives

1 Review risk characterization presented in the watershed ERA - Since completion of the watershed ERA, significant ecological data have been collected at RFETS through the annual ecological monitoring program As a result, additional information is available to help reduce the uncertainty associated with conclusions of the watershed ERA

2 Evaluate potential for ecological risk from PCOC distributions in the IA. The IA has been highly developed and contains little valuable ecological habitat. However, future land use at the IA may allow for development of wildlife habitat. Therefore, assessment of the area is required to determine whether remediation is necessary to reduce ecological risk from chemical stressors. This effort should include assessment of potential exposures within the IA, as well as a summary of studies regarding potential migration of contaminants from the IA to downgradient areas

7.4.2 DQO Step 2: Identify the Decision

As noted previously, the initial portion of the CRA ERA is equivalent to an expanded version of Steps 1 and 2 of the EPA process for conducting ERAs at Superfund sites (EPA 1997c) The risk assessment includes the following general questions

- Are adequate data available to conduct the ecological screening evaluation?

17

- Is adequate information available to conclude that ecological risks are negligible and remediation to attenuate ecological risks is not necessary?

This general decision can be subdivided into the following decisions

1 Has the nature and extent of chemicals, metals and radionuclides within IHSSs, PACs, UBC Sites, BD Sites, and WS Areas been identified with adequate confidence, based on site history (process knowledge) and analytical data?

2 Are residual long-term ecological risks in the IA and BZ acceptable, based on post-closure uses? Residual risks are those that will remain after remediation, if any, is conducted If remediation is not conducted in an area, risk assessment will be based on existing data If residual concentrations exceed screening levels, further evaluation, management, or remediation is necessary

   a. This decision will be based aggregating data from habitat "patches" for comparison to screening values For terrestrial habitats, a patch will be composed of a designated area, such as a mesa top or segment of riparian corridor For aquatic habitats, stream segments and ponds (i e , impoundments) will composed habitat patches Patch designations will be made on a case-by-case basis and subject to concurrence by the regulatory agencies prior to finalization

   b For assessment of risk to nonprotected species, risk assessors will have the choice of comparing the maximum concentration or an area-weighted average from a patch to the corresponding screening levels If an area-weighted average is used, the 95% (i e , alpha = 0 05) UCL of the mean will be the parameter compared to the screening level

   c For assessment of risk to protected species (e g , *Zapus hudsonius preblei*), maximum concentrations will initially be compared to the screening levels If the maximum concentration in a habitat patch exceeds the screening level, each sample result that exceeds the screening level and the corresponding locations will be identified

3 Is further risk characterization necessary to make remedial decisions about the RFETS Site or parts thereof? If further risk characterization is necessary, will more extensive analysis of existing information be sufficient?

7.4.3 DQO Step 3: Identify the Inputs to the Decision

The information needed to resolve the CRA decision statements is listed below.

1 Data and results from previous ERAs conducted at RFETS,

2 Ecological data that have become available since the completion of previous ERAs (e g , the Integrated Ecological Monitoring program), and

3 Existing data for areas under consideration This may include data from RI reports, RFI/RI Reports, FS/ CMS, Remedial Action Reports, IMP Reports, Pre-Demolition

18

Survey Reports, and other projects and data sets, including IASAP-generated, historical, and IMP data (e g , concentrations of COCs in surface and subsurface soil, surface water, groundwater, air, and biota), that will be used as inputs to the CRA

4 Data on distribution of environmental contamination within the IA These data will be collected based on the IASAP (DOE 2000) The sampling plan will consider available information, sampling data, and risk assessment requirements, as documented in the CRA Methodology This data will be used to determine an adequate sampling plan for IHSSs, PACs, UBC Sites, BD Sites, and WS Areas to support CRA decisions

5 Data from sources identified above will be screened through the DQF for each type of environmental medium as prescribed in this CRA Methodology This will ensure the reliability of the data used in the risk assessment

6 Ecotoxicologically based screening levels for abiotic environmental media will be needed to screen the data set resulting from the DQF

7.4.4 DQO Step 4: Define the Study Boundaries

Decision boundaries are used to determine the areas from which data will be used, and identify where future sampling will occur. These decision boundaries are listed below.

1 Only data from characterization and remediation activities will be used This is anticipated to include the areas around the A- and B-series ponds In no event will the assessment area extend beyond the current RFETS boundary

2 A CRA contaminant transport modeling effort will include assessment of the air and surface water pathways on a Sitewide basis The ERA portion of the CRA will consider PCOCs in surface water, but will not include the air pathway The contaminant load to surface water includes COC transport from surface soil, unsaturated and saturated zone soil, building debris, and sediments The modeling effort will support the derivation of EPCs for land uses identified on Figure 1 of Attachment 5 to RFCA (DOE 1996a)

3 Soil will be assessed generally from the land surface to the top of the saturated zone or top of bedrock, as appropriate

7.4.5 DQO Step 5: Develop a Decision Rule

The decision rules that describe how the data will be evaluated are listed below. The criteria used to determine whether ecological risks are acceptable are listed below

1 If maximum concentrations for a given area are equal to or less than the corresponding screening level, then no further analysis or remediation is needed

2 If 95% UCL of the mean for a given patch is equal to or less than the screening level, then risks will be considered acceptable and no further analysis or remediation is needed

19

3 If the screening level is less than the specified parameter (maximum or 95% UCL), then further analysis, management, or remediation is necessary Further analysis can be quantitative or qualitative in nature

7.4.6 DQO Step 6: Specify Tolerable Limits on Decision Errors

Sources of uncertainties in the risk assessments will be identified and minimized

7.4.7 DQO Step 7: Optimize the Design

The nature and extent of COCs in IHSSs, PACs, UBC Sites, and WS Areas will be assessed to support the CRA The nature and extent of COCs in IHSSs, PACs, UBC Sites, and WS Areas in the IA will be determined according to the IASAP The nature and extent of COCs in IHSSs, PACs and WS Areas in the buffer zone will be determined according to the BZSAP (to be completed in FY01) The nature and extent of COCs in BDs will be determined using the building-specific Pre-Demolition Survey Reports

7.5 DATA TYPES

The CSMs suggest that ecological receptors may be exposed to PCOCs in abiotic and biological media For purposes of the risk assessment, the inhalation exposure route will be considered insignificant compared to ingestion pathways for terrestrial wildlife (EPA 2000b) Biological tissue analysis results will not be used in the initial phase of the IA and CRA assessments However, potential uptake of PCOCs into prey and forage species will be considered in development of the screening levels Therefore, data on PCOC concentrations in soil, surface water, and sediment will be evaluated to support the CRA

For the IA, additional soil sampling will be conducted to support the remediation and risk assessments PCOC concentrations in soil and sediment should be expressed as "total recoverable" (e g , sample prepared for analysis by EPA Method 3050 or equivalent) PCOC concentrations in surface water that are to be compared to water quality standards for protection of aquatic life should be expressed as "dissolved" (i e., filtered with a 0 45 µm filter prior to analysis) This is because water quality standards are based on the dissolved fraction Surface water data used to assess risks to wildlife drinking the surface water will be based on "total recoverable" (i e , unfiltered) analyses.

For new data to be collected as part of the IA investigation, laboratory analytical methods will be selected to provide data with adequately low method detection limits (MDLs), and practical quantitation limits (PQLs) to allow meaningful comparison to ecological screening levels in abiotic media

In addition to the comparison of screening levels directly to analytical data, potential future exposures will be estimated by modeling contaminant fate and transport In particular, models will be used to estimate PCOC concentration in storm water runoff from potentially contaminated soils and groundwater that may surface at seeps downgradient of the IA Both sources of water could contact aquatic biota or wildlife.

80

7.6 DATA SUFFICIENCY FOR ECOLOGICAL RISK ASSESSMENT

Adhering to the specifications of the DQOs as outlined above will ensure the adequacy of data for use in the ERA In addition, use of the DQF (described in Section 2 2 and 3 1 1 above) will help ensure that the quality of data is consistent with RFETS standards

7.7 SUMMARY OF MAIN SOURCES OF UNCERTAINTY

Many sources of uncertainty are associated with ERAs and other environmental investigations Suter (1990) identify three main categories of uncertainty sources

- The fundamentally stochastic (random) nature of the environment,
- Incomplete knowledge of the system under study, and
- Uncertainty associated with execution of the study

The stochastic variability of nature can be quantified and characterized but not reduced, because it is a fundamental property of the system. Some aspects of ecological systems are predictable at some level, but the components that are amenable to measurement often have a significant amount of random variability associated with them Variability within a data set can be reduced by narrowing the scope of sampling to include items of similar qualities, such as collecting only female mice of a certain age and weight However, the general applicability of the results is proportionately narrowed

The second source of uncertainty refers to scientific ignorance of the system under study This source is theoretically reducible, but only at the considerable cost of exhaustive sampling or experimental manipulation The goal of the IA and BZ Characterization and subsequent risk assessments is not to eliminate uncertainty. Rather, the uncertainty should be characterized in a way that allows it to be used in making informed risk management decisions (EPA 1988a) This type of uncertainty has traditionally been countered by application of conservative assumptions, but this practice can lead to inconsistent estimation of risk, take accurate estimates of uncertainty out of the decision process, and generate "false positives" (Paustenbauch 1990) Nevertheless, assumptions were required in the exposure analyses and toxicity assessments (development of TRVs) because of lack of more accurate or Site-specific information Therefore, where needed, assumptions were conservative to ensure all exposure and risk estimates were biased in one direction and the chance of underestimating risk was minimized (EPA 1994c)

The third source of uncertainty involves execution of data collection and analysis This source of uncertainty includes inappropriate sampling locations, inaccurate or inconsistent sample collection methods, and data recording errors This type of uncertainty should be addressed in quality assurance (QA) plans and Site audits Sampling for the RFETS ERAs was performed in accordance with standard operating procedures (SOPs) for collection of ecological data at the Rocky Flats Plant (DOE 1991), and field audits were conducted by independent EG&G Rocky Flats, Inc (EG&G) and DOE contractors

Biological tissue samples were collected and analyzed for specific contaminants such as metals, radionuclides, and PCBs Chemical concentrations in tissues are generally the most

reliable indicator of exposure for chemicals, such as those that are not rapidly metabolized (Suter 1993) Ecological effects were extrapolated from surrogate measures or short-term analyses such as toxicity tests Toxicity tests were conducted at RFETS for surface water and sediments, but not for soil

Specific sources of uncertainty, assumptions, and potential effects on interpretation of results are summarized in Table 7-3

7.8 PCOC LIST DEVELOPMENT

A Sitewide PCOC list will be developed in a process that will combine (1) previous risk assessment results (ECOC list) from the Site, (2) eliminate analytes with naturally occurring background concentrations, (3) eliminate chemicals characteristically too volatile to survive in surface soil for any significant length of time, and (4) group together analytes that have similar toxicity characteristics such as PCBs, PAHs, and phthalates

7.9 DERIVATION OF ECOLOGICAL RISK SCREENING CRITERIA

As noted previously, the RFETS ERA methods are being amended, in part, to include risk-based screening criteria for soil Screening criteria will be expressed as concentrations (e.g., mg/L), and so thus can be compared directly to data on PCOC concentrations in soil The criteria will be developed for various types of receptors (omnivorous mammals, birds, etc.) and will represent ecotoxicologically 'safe' exposures for each of the PCOCs to each receptor group This approach is similar to development of PRGs for HHRAs (EPA 1991), and allows more efficient evaluation of environmental data for possible risk of toxic exposures

As noted previously, risks to ecological receptors in the BZ were evaluated in the watershed ERA Therefore, additional exposure and effects assessment is expected to focus on the IA, which currently does not contain significant ecological habitat ERA activities in the IA will focus on assessing potential ecotoxicological risk from residual contamination in soil Therefore, development of screening criteria for soils represents an important data need for completing the ERA

Screening criteria will be developed by multiple methods Criteria developed for other sites or programs may be used directly for the ERA if the assumptions underlying the development of the criteria are applicable to RFETS Potential sources for such criteria include draft EPA ecological soil screening levels (EcoSSLs) and published methodology for deriving the criteria (EPA 2000b) In addition, the government of the Netherlands has published soil screening guidelines for pesticides and metals in soil (RIVM 1997a, 1997b)

Table 7-3 Sources of Uncertainty and Their Potential Effects on Results and Conclusions of the Walnut Creek and Woman Creek ERAs

Source	Effect	Remark
Toxicity Assessment		
1 Lack of specific toxicity information for exposure of Rocky Flats species to COCs	May over- or underestimate critical effects concentrations	This is especially important in assessment of potential toxicity to vegetation and exposure of small mammals to burrow air Toxicity information is also lacking for other receptors/chemicals Exposures for all PCOCs were calculated and presented
2 Variable endpoints used to set TRVs	Inconsistent estimate of effects	Toxicity information was derived from open literature, standardized tests were not generally available for non-aquatic species
3 Use most sensitive species in literature to set TRV	May over- or underestimate critical effects concentrations	Data for most sensitive species was used to protect greater number of species
4 Estimation of NOEL from other data	May over- or underestimate critical effects concentrations	NOELs are derived from LOELs by dividing by 10 This is probably conservative since NOELs are not usually 0 1 of LOELs
Exposure Assessment		
1 Number of samples may not be adequate to estimate exposure	May over- or underestimate exposure if data are not representative of true condition	UCL_{95} or maximum concentration was used to estimate exposure Conservative assumptions were used in estimating uptake of organic chemicals by aquatic and terrestrial biota to minimize chance of underestimating risk
2 Use data from all soil depths to estimate vegetation and burrow air exposures	May overestimate exposure if highest concentrations are from depths not accessible by roots or small mammals	Depth information was not uniformly available for subsurface soil (borehole samples) data
3 Tissue analytes identified before contaminants known	Data on chemicals concentration in biological tissue not available for some PCOCs	BCFs and transfer coefficients from the literature were used in modeling uptake of some COCs
4 Abiotic sampling not designed specifically for ecological risk assessment	Data on chemical concentrations in abiotic media may not represent true exposure point concentrations	The exposure assessment adopted a screening level approach that was based on conservative assumptions and is designed to minimize chance of underestimating exposures

Table 7-3 Sources of Uncertainty and Their Potential Effects on Results and Conclusions of the Walnut Creek and Woman Creek ERAs (cont.)

Source	Effect	Remark
Exposure Assessment		
5 Assume all portions of source areas used equally	May over- or underestimate exposure for a given point in source area	Source area boundaries were chosen to include all potentially contaminated areas UCL_{95} or maximum concentrations were used in exposure estimates to yield conservative exposure estimates
6 Assume all chemicals in abiotic and biotic sample are bioavailable	May overestimate exposure to radionuclides and metals	Not all contaminants taken up are assimilated This is especially true for metals which form significant portions of natural rock matrices
7 Assume equilibrium between VOCs in soil and burrow air	May overestimate concentration of VOCs in burrow air	Burrows are usually not closed systems Therefore, diluting effect of exchange with ambient air not included in exposure estimate
8 Assignment of frequency distributions in simulation modeling	May over- or underestimate probability of exceeding critical value	Mean values are probably not affected, but values in "tails" of distribution may be over- or under-represented
9 Use of mean ingestion rates, body weights, and home range sizes in simulation modeling	May over- or underestimate probability of exceeding critical value	Means were used because data from literature were not amenable to statistical analysis
Effects Assessment		
1 Quality of water and sediment toxicity tests	Lack of confidence in test results	Prescribed temperature and survival of organisms in controls were not met in some tests
2. Phytotoxicity tests not conducted	Importance of PCOC concentrations exceeding TRVs for vegetation is unvalidated	No obvious areas of vegetative stress were observed during field investigations Some areas with weedy species may indicate stress to community from physical disturbance and may mask chemical stress
3 Tissue concentrations or biomarkers not available for some ECOCs	Estimates of exposure and effects uncertain	Specific measures of sublethal physiological stress are needed to evaluate effects of compounds such as PAHs
4 Tissue concentrations not available for upper level vertebrate consumers	No direct measure of exposure	Conventional methods were supplemented by site-specific data on uptake ratios used to estimate uptake

84

SSVs from each of these sources will be used as appropriate In addition, EPA describes a process by which data on toxicity and bioaccumulation can be used to develop SSVs This method, combined with data on toxicity and bioaccumulation, will be used to develop SSVs for which previously developed SSVs are not available Species may contact soil contaminants through incidental ingestion of soil during feeding, or through ingestion of vegetation or prey items that have become contaminated through contact with soil Estimation of SSVs must consider both components The general approach to calculating SSVs from available information is discussed below

In cases where applicable screening criteria are not available for a particular PCOC or receptor, screening criteria may be developed specifically for application at RFETS The screening criteria, as well as methods used to identify them, may be updated as needed to include future developments in toxicological information, methods to evaluate bioavailability, or other factors that may affect estimation of screening criteria

7.9.1 Basic Approach for SSV Estimation

The conventional approach to estimating risk of toxicological exposure has been to compare the estimated exposure or dose for a given site or chemical to benchmark exposures associated with a known response The benchmark value is the TRV. In risk screens, the TRV is usually associated with negligible toxicity and thus represents a "safe" exposure

Results of this comparison are often expressed using the HQ approach (EPA 1997c), which is the ratio of the estimated exposure to the TRV

$$HQ = \frac{Dose_{total}}{TRV} \qquad \text{(Equation 7-1)}$$

where

HQ	=	hazard quotient (unitless)
$Dose$	=	dose, or total intake of the potentially toxic chemical
TRV	=	toxicity reference value

An HQ of less than or equal to 1 indicates exposures are less than the TRV and are usually associated with negligible risk An HQ greater than 1 indicates exposures exceed the TRV and further analyses may be necessary to characterize the extent and magnitude of risk Risk estimates using this approach depend upon accurate estimation of dose and development of reliable TRVs

As noted above, dose can have at least two components

$$Dose_{total} = Dose_{food} + Dose_{soil} \qquad \text{(Equation 7-2)}$$

Food items, whether plant or animal, may take up contaminants from contact with soil The extent to which this occurs can be described by a bioaccumulation factor (BAF) Given the concentration of a chemical in soil (C_{food}) and a BAF, the concentration of a chemical in a particular food (C_{food}) item can be estimated as

85

$$C_{food} = C_{soil} * BAF \qquad \text{(Equation 7-3)}$$

In many cases, BAFs vary inversely with soil concentration Therefore, use of one BAF for all soil concentrations may overestimate exposure at higher soil concentrations, and underestimate at lower C_{soil} The draft EPA guidance (EPA 2000b) on calculating SSVs accounts for this phenomenon by using chemical-specific BAF equations generated from regression analysis to estimate SSVs SSV estimation for RFETS may also use such equations However, for simplicity, the following discussion assumes constant BAF values

SSV development involves using these relationships to identify the C_{soil} that results in an intake of a chemical equal to the TRV (i e , HQ = 1)

When the BAF is used in standard chemical intake equations (EPA 1997c), the HQ is estimated as the following

$$HQ = \frac{\left[\sum_{i=1}^{N}(BAF_i * P_i * IR_f * AF_f) + (P_s * IR_f * AF_s)\right] * C_{soil} * AUF}{TRV} \qquad \text{(Equation 7-4)}$$

where

BAF_i	=	bioaccumulation factor for the ith prey item from soil (unitless)
P_i	=	proportion of the ith prey item of the total diet (unitless)
IR_f	=	ingestion rate of food (kg food/kg body wt/day)
AF_f	=	gastrointestinal absorption factor of food (unitless)
P_s	=	soil intake as a proportion of dietary intake (unitless)
AF_s	=	gastrointestinal absorption factor for soil (unitless)
C_{soil}	=	PCOC concentration in soil (mg/kg)
AUF	=	area use factor (proportion of feeding range being assessed) (unitless)
TRV	=	toxicity reference value (mg PCOC/kg body wt/day)

If the AF_s, AF_f, and AUF are assumed to have values of 1, Equation 4 can be solved for C_{soil}

$$C_{soil} = \frac{TRV * HQ}{IR_f * (P_s + BAF_i)} \qquad \text{(Equation 7-5)}$$

If the HQ is assigned a value of 1 to represent exposure equal to the TRV, the resulting equation can be used to estimate the SSV

$$SSL = \frac{TRV}{IR_f * (P_s + BAF_i)} \qquad \text{(Equation 7-6)}$$

or

For carnivorous mammals and birds (upper trophic level)

86

$$SSL_{pred} = \frac{TRV}{IR_f * (P_s + (BAF_i * BAF_k))} \qquad \text{(Equation 7-7)}$$

where

BAF_k = Bioaccumulation factor for transfer of (PCOC) from first trophic level prey items to second trophic level consumers (i e , small mammals)

It should be noted that if small areas are being considered, or gastrointestinal absorption efficiencies for specific chemicals are known, the AUF and AFs can be set to values other than 1 and used to calculate SSVs Baseline calculation of SSVs for RFETS assigns values of 1 to these factors because this approach is consistent with EPA guidance for screening-level assessments in which conservative assumptions are made to avoid underestimating risk

7.9.2 Receptor-Specific SSV Estimation

The assessment endpoints for which exposure to soil is an important pathway are mammalian and avian wildlife TM-2 of the RFETS methodology identifies species of wildlife to represent the general assessment endpoints for ERAs TM-2 also identifies the intake parameters for estimating dietary ingestion rates, home range sizes for assigning AUFs, and approximate dietary composition for the representative species

Calculation of specific SSVs for representative species will be presented in an attachment to the CRA Methdology. Intake parameters, BAFs and equations, and TRVs will also be presented in the attachment Each of the factors may be updated as additional or better information for estimating the parameters becomes available

7.9.3 Use of Criteria

As noted in Section 7.1, the initial phases of the CRA and IA ERAs is structured to be consistent with the screening-level risk assessment portions of EPA's eight-step process (EPA 1997c) However, unlike most other screening-level risk assessments, a substantial amount of information is available for evaluating ecological risk at RFETS, including a comprehensive evaluation of ecological risk for the BZ. In addition, remediation has been and will be conducted within the IA and BZ as part of the overall closure strategy As a result, the CRA approach includes a more comprehensive screening approach to make full use of the existing information and account for risk reductions resulting from remedial actions

In accordance with EPA guidance, risk managers and risk assessors will use the information generated by the screen to determine whether additional risk analysis is necessary to make decisions on whether remediation is necessary to reduce risk to ecological receptors

Risk screening criteria will be used to assess the potential for ecotoxicity by comparing criteria directly to Site data If PCOC concentrations in the samples of concern exceed the risk criterion, then further action is required Further action can be defined as further qualitative and/or quantitative data analysis of existing data, assessment of uncertainty,

87

collection of additional data to reduce uncertainty, or remedial action to reduce the exposures

The approach to comparing screening criteria to Site data may vary with the specific application Screening criteria are estimated to represent safe exposures for chronic exposure of individual organisms Therefore, selection and aggregation of Site data for comparison to screening criteria must consider the overall assessment endpoints and final objective of the risk evaluation and subsequent actions that may occur Except for protected species, assessment endpoints are intended to protect populations of receptors at RFETS Comparison of PCOC concentrations from individual grab samples may be overly conservative because the results from one location may not adequately represent risk throughout the population or habitat at RFETS However, assessment of individual sample results may be desirable if decisions regarding specific actions at a particular location depend on the comparison, such as during removal actions

When the objective is protection of populations, data from habitat " patches" should be used to calculate the 95 % UCL of the mean, which is then compared to risk criteria A habitat patch is meant as a contiguous portion of vegetation community or designated wildlife habitat In most cases, this approach is probably overly conservative in that each patch likely does not represent a viable population without emigration and immigration from nearby patches and metapopulations However, such an assessment will allow risk managers to determine whether more intensive studies are needed

For assessment to individuals, the 95% UCL for areas the size of an individual home range can be used for comparison to screening criteria The approach to data aggregation may differ with the assessment endpoint or amount of data available for a given area. In any case, the uncertainty of any data aggregation scheme should be clearly described

7.10 SCIENTIFIC-MANAGEMENT DECISION POINT FOLLOWING SCREENING–LEVEL ASSESSMENT

As discussed in previous sections, the eight-step EPA ERA guidance (EPA 1997c) includes specific decision points at which risk assessors and risk managers convene to determine the direction of the ERA The decision points are SMDPs. At the end of the SLERA in Step 2, an SMDP occurs to determine whether additional analyses are needed The decision at this point has three possible outcomes

1 There is adequate information to conclude that ecological risks are negligible, and therefore, there is no need for remediation on the basis of ecological risk

2 The information is not adequate to make a decision, and the ERA process should continue

3 The information indicates a potential for adverse ecological effects and a more thorough assessment is warranted

For RFETS, a substantial amount of data is available to conduct the exposure and risk screen In addition, previous ERAs included extensive exposure and risk screening for source areas in the BZ, and effect-based data (e g , toxicity testing and chemical residues) on direct effects Results of the watershed ERAs indicated very limited ecological risk, primarily

associated with the A- and B-series retention ponds The uncertainties identified in the watershed ERAs will be addressed in the CRA using ecological and chemical data, and results of surface water and groundwater, water balance, etc , modeling As a result of the IA investigation, soil with PCOC concentrations in excess of screening levels will have been removed Therefore, no additional risk analysis will be necessary to determine future remediation needs for the IA Results of the SMDP will be documented in the CRA report as appropriate

89

8.0 COMPREHENSIVE RISK ASSESSMENT REPORT ORGANIZATION

The CRA report will be written as a "stand-alone" document for RFETS and will support the selection of the final remedial design and regulatory closure of the Site The report will contain the following sections

Executive Summary,
Section 1 0 Introduction,
Section 2 0 Site Description,
Section 3 0 COC Identification,
Section 4 0 Scenario and Pathway Identification,
Section 5 0 Exposure Assessment,
Section 6 0 Toxicity Assessment,
Section 7 0 Risk Characterization and Uncertainty Analysis,
Section 8 0 Summary,
Section 9 0 References, and Appendices

The following sections describe the contents of each section of the CRA report These subsections discuss only minimum information for the CRA Additional information may be included that describes the methodologies, approaches, and results.

Executive Summary

The Executive Summary will be a stand-alone document that concisely summarizes the results of the CRA and includes any supporting information as necessary

Section 1.0 Introduction

The Introduction will summarize purpose, scope, objectives of the CRA, and organization RFCA requirements and a chronology of the previous investigations and accelerated actions will also be discussed

Section 2.0 Site Description

This section will present a brief summary of previous reports that provide a description of the current disposition of IHSSs, PACs, and UBC sites, remedial actions completed, current site configuration, meteorology and climate, hydrogeology, flora and fauna; demographics and local land use, determination of potential contaminants of concern, nature and extent of contamination, and contaminant migration pathways Tables, figures, and maps will be used to summarize accelerated actions, contaminants remaining; media at the site; general and specific site areas and locations, and residual contaminant detection locations. The reader of the CRA report will be referred to source documents for further detail

Section 3.0 Human Health COC Identification

The COC identification methodology and its application in the selection of COCs will be presented Background comparisons for inorganics and radionuclides including applicable statistical tests and resulting potential COCs, will be discussed The COC screening methodology will be presented and applied to derive a list of COCs to be carried through the risk assessment Tables 3-1, 3-2, and 3-3 in this CRA Methodology provide examples of summary statistics and the resulting COCs, Figure 3-1 shows the COC process

90

Section 4.0 Human Health Scenario and Pathway Identification
Development of exposure scenarios and identification of exposure pathways will be discussed in relation to potential land uses The CSM will be presented A discussion will be provided for each current and potential onsite and offsite land use and associated exposure scenarios Potential receptors for each land use will be identified, and justification of the selection of exposure pathways in the CSM will be provided

Section 5.0 Human Health Exposure Assessment
This section will first present pathway-specific information such as intake equations and modeling data, followed by information that is both scenario-specific and pathway-specific such as exposure parameters and exposure concentrations Where modeling is used to provide exposure concentrations, a brief summary of the model will be provided The calculated EPCs and chemical intakes will be presented for each scenario and potential health outcome Tables and figures may include model applications, chemical-specific constants, intake equations and parameters, and resulting receptor intakes Tables 6-1, 6-2, and 6-3 in this CRA Methodology provide examples

Section 6.0 Human Health Toxicity Assessment
The toxicity assessment will provide toxicity information for COCs, including carcinogenic and noncarcinogenic toxicity factors, critical effects, uncertainty or modifying factors, and sources Tables will be used to summarize toxicity values for each COC, with toxicity profiles where applicable presented as text Tables 3-4, 3-5, and 3-6 in this CRA methodology provide examples of summary toxicity information

Section 7.0 Characterization and Uncertainty Analysis
The risk characterization will present the methodology and results of combining the information provided by the exposure and toxicity assessments The results provide numerical estimates of potential health carcinogenic risks, noncarcinogenic health hazards, and radiological dose The nature and weight-of-evidence supporting the risk estimates and the magnitude of uncertainty will be discussed Pathway and exposure scenario-specific carcinogenic risks noncarcinogenic HIs, and radiation dose will be presented and discussed Sources of uncertainty and their potential impact on the assessment will be presented Monte Carlo analysis may be included. Tables 6-1, 6-2, and 6-3 of this CRA Methodology provide examples of the risk and dose characterization calculations

Section 8.0 Ecological Screen Results
This section will present the results of the direct comparison of the screen criteria against the Site environmental data for the IA. In addition, this section will present any additional analyses on the Site BZ environmental data deemed appropriate

Section 9.0 Summary
The Summary will present an overview of the methodology implemented for the CRA and the results Text, tables, and figures will summarize the entire CRA The section will also include summary tables of risk and dose, and a discussion of risk drivers and associated uncertainties

Section 10.0 References
This section will include all references used throughout the CRA

Appendices

Appendices will include additional information that may be helpful to the reader about the background assumptions or approach to any aspect of the CRA The following items briefly describe potential contents for the appendices to the CRA Additional appendices may be needed

- Data Summary – This section will present data used in the report and discuss data sufficiency, screening and cleanup
- Background Comparison – This appendix will discuss the background analysis process and results Using statistical analysis, inorganic chemical concentrations or radionuclide activities at or below background levels will be eliminated from further consideration
- Fate and Transport Model Descriptions and Applications – This appendix will provide a detailed description of the models used in the CRA, including methodologies and assumptions Applications of each model will be described and discussed Examples of models include groundwater modeling, soil-gas modeling, and atmospheric modeling
- 95% UCL calculations for Human Health COCs – This appendix will provide a brief description of the methodologies and assumptions used to determine the 95% UCLs for the COCs It may also include tables to summarize the results of the calculations for each COC
- Ecological Risk-Based Screening Criteria - This appendix will present the risk-based screening criteria for soil The criteria will be developed for major receptor groups onsite (omnivores and mammals, piscivorous birds, etc)

9.0 REFERENCES

Crump, K S , H A Guess, and K L Deal, 1977, Confidence Intervals and Tests of Hypotheses Concerning Dose Response Relations Inferred From Animal Carcinogenicity Data, Biometrics, Vol 33, pp 437-451

DOE, 1991, Final Phase III RFI/RI Work Plan, Revision 1, 881 Hillside Area (Operable Unit No 1), U S Department of Energy, Rocky Flats Plant, March

DOE, 1993a, Background Geochemical Characterization Report, U S Department of Energy, Rocky Flats Plant, September

DOE, 1993b, Policy Framework and Implementation Plan for Using Ecological Risk Assessment at DOE Facilities, DOE/RL/01830-H16, U S. Department of Energy, Washington, D C

DOE, 1993c, Draft Ecological Risk Assessment Guidance for Preparation of Remedial Investigation/Feasibility Study Work Plans, DOE/EH-0338T, U S Department of Energy, Washington, D C

DOE, 1995a, Geochemical Characterization of Background Surface Soils· Background Soils Characterization Program, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, Final Report, May

DOE, 1995b, Draft Final Phase I RFI/RI Report, Woman Creek Priority Drainage Operable Unit No 5, U.S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, Appendix N, October

DOE, 1995c, Phase I IM/IRA Decision Document for Operable Unit 7, Present Landfill, Draft Report, U S. Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado

DOE, 1996a *Rocky Flats Cleanup Agreement,* Joint Agreement between the U S Department of Energy, the U S Environmental Protection Agency, the Colorado Department of Public Health and Environment and the State of Colorado, July 19, 1996

DOE, 1996b, Final RFI/RI Report, OU 3 Offsite Areas, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, June

DOE, 1996c, Final Ecological Risk Assessment Methodology· Technical Memorandum Ecological Chemicals of Concern (ECOCs) Screening Methodology, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, June

DOE, 1996d, Final Ecological Risk Assessment Methodology. Technical Memorandum Sitewide Conceptual Model, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, June

DOE 1999a, Implementation Guidance Document (IGD), U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado

DOE, 1999b, Industrial Area Characterization and Remediation Strategy Report, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, September

DOE, 2000, Preliminary Data Quality Objectives for the Industrial Area Sampling and Analysis Plan, U S Department of Energy, Rocky Flats Environmental Technology Site, Golden, Colorado, July

Efroymson, R A , G W Suter II, B E Sample, D S Jones 1997, Preliminary Remediation Goals for Ecological Endpoints, ES/ER/TM-162/R2

EPA, 1988a, Federal Guidance Document No 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, Office of Radiation Programs, EPA/520/1-88/020, U S Environmental Protection Agency, Washington, D C

EPA 1988b, Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA, Interim Final, EPA/540/G-89-004, U S Environmental Protection Agency, Washington, D C , October

EPA, 1989a, Risk Assessment Guidance for Superfund, Volume I Human Health Evaluation Manual (Part A), EPA 154011-891002, Office of Emergency and Remedial Response, U.S Environmental Protection Agency, Washington, D.C.

EPA, 1989b, Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual, Office of Emergency and Remedial Response, U S Environmental Protection Agency, Washington, D C

EPA 1990, National Oil and Hazardous Substances Pollution Contingency Plan, Final Rule, 40 CFR Part 300, U S. Environmental Protection Agency, Washington, D C.

EPA, 1991, Risk Assessment Guidance for Superfund, Volume I. Human Health Evaluation Manual (Part B), Office of Emergency and Remedial Response, U S. Environmental Protection Agency, Washington, D C., December

EPA, 1992a, Guidance for Data Usability in Risk Assessment, (Parts A and B), Office of Emergency and Remedial Response 9285 7-09A, April.

EPA, 1992b, Guidelines for Exposure Assessment, Federal Register, Vol. 57, No. 104, U S Environmental Protection Agency, Washington, D C , May

EPA, 1992c, Guidance on Risk Characterization for Risk Managers and Risk Assessors, F H Habicht, II, Memorandum, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D C , May

EPA, 1992d, Framework for Ecological Risk Assessment· Risk Assessment Forum, EPA/630/R-92/001, U S Environmental Protection Agency, Washington D C , February

EPA, 1993, Federal guidance Document No 12, External Exposure to Radionuclides in Air, Water, and Soil, EPA-402-R-93-081, U S Environmental Protection Agency, Washington, D C , September.

EPA, 1994a, Guidance for the Data Quality Objective Process, EPA QA/G4, EPA/600/R96/055 U S Environmental Protection Agency, Washington, D C

EPA, 1994b, Evaluating and Identifying Contaminants of Concern for Human Health, No RA-03 Contaminants of Concern, Region 8 Technical Guidance, U S Environmental Protection Agency, Washington, D C , September

EPA, 1994c, Ecological Risk Assessment Guidance for Superfund Process for Designing and Conducting Ecological Risk Assessments, Review Draft, Environmental Response Team, Edison, New Jersey, September

EPA, 1995, Policy for Risk Characterization, U S Environmental Protection Agency, Washington, D C , March

EPA, 1997a, *Health Effects Assessment Tables (HEAST),EPA-540-R-97-036,* Office of Solid Waste and Emergency Response, U S Environmental Protection Agency, Washington, D C

EPA, 1997b, *Policy for Use of Probabilistic Analysis in Risk Assessment at the U S Environmental Protection Agency* EPA/630/R-97/001 U S Environmental Protection Agency, Washington, D C

EPA, 1997c, Ecological Risk Assessment for Superfund Process for Designing and Conducting Ecological Risk Assessments, U S Environmental Protection Agency, Washington D C (Interim Final), (July)

EPA, 1999a, Federal Guidance Report No 13, Cancer Risk Coefficients for Environmental Exposure to Radionuclides, EPA-402-R-99-001, U S Environmental Protection Agency, Washington D C , September

EPA, 1999b Screening Level Ecological Risk Assessment Protocol For Hazardous Waste Combustion Facilities (Peer Review Draft), Office of Solid Waste and Emergency Response EPA 530-D-99-001A, U S Environmental Protection Agency, Washington D.C , August.

EPA, 2000a, Integrated Risk Information System (IRIS), URL: http://www epa.gov/iris, U S. Environmental Protection Agency, Washington, D.C

EPA, 2000b, Ecological Soil Screening Level Guidance (Draft), Office of Emergency and Remedial Response, U S Environmental Protection Agency, Washington D C , July

Gilbert, R O and Simpson, J.C., 1992, Statistical Methods for Evaluating the Attainment of Cleanup Standards Volume 3. Reference Based Standards for Soils and Solid Media, Pacific Northwest Laboratories Publication PNL-7409, Vol 3, Rev 1

Helsel, D R 1990, Less than Obvious· Statistical Treatment of Data Below the Detection Limit, Environmental Science and Technology, v24, n 12, pp 1766-1774

IAEA (International Atomic Energy Agency), 1992, Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards, Technical Reports Series 332 IAEA, Vienna.

ICRP 1975, Report on the Task Group on Reference Man, International Commission on Radiological Protection (ICRP), Publication 23

95

Jefferson County, 1994, Data provided by Jefferson County Department of Open Space from surveys performed in 1994, Jefferson County, Colorado

Jefferson County, 1996, Data provided by Jefferson County Department of Open Space from surveys performed in 1996, Jefferson County, Colorado

Kaiser-Hill 1999, Air Transport and Deposition of Actinides at the Rocky Flats Environmental Technology Site, FY99 Report, September

Kaiser-Hill, 2000a, Air Transport and Deposition of Actinides at the Rocky Flats Environmental Technology Site, FY00 Report, September

Kaiser-Hill, 2000b, Fiscal Year 2000 Actinide Migration Evaluation Data Quality Objectives, Rocky Flats Environmental Technology Site, March

NCRP, 1985, General Concepts for the Dosimetry of Internally Deposited Radionuclides, National Council on Radiation Protection and Measurement, NCRP Report

Norton, S B , D J Rodier, J H Gentile, W H vanderSchalie, W P Wood, and M.W Slimak, 1992, A Framework for Ecological Risk Assessment at the EPA, Environmental Toxicology and Chemistry, 11 1663-1672

Opresko, D M , B E Sample, and G W Suter II, 1994,Toxicological Benchmarks for Wildlife 1994 Revision, Oak Ridge National Laboratory, ES/ER/TM-86/R1, September.

ORNL (Oak Ridge National Laboratory), 1994, Toxicological Benchmarks for Screening Contaminants of Potential Concern, 1994 Revision

Paustenbach, D J ed , 1990, The Risk Assessment of Environmental and Human Health Hazards A Textbook of Case Studies, John Wiley & Sons, New York

Rasmussen, J B , D J Rowan, D R S Lean, and J H Carey, 1990, Food Chain Structure in Ontario Lakes Determines PCB Levels in Lake Trout (*Salvelinus namaycush*) and Other Pelagic Fish, Canadian Journal of Fisheries and Aquatic Sciences, 47 2030-2038.

RIVM (Rijksinstituut Voor Volksgezondheid en Milieu), 1997a, National Institute of Public Health and Environment Maximum Permissible Concentrations and Negligible Concentrations for Pesticides Authors. T Crommentuijn, D.F Kalf, M D. Polder, R. Posthumus and E J van de Plassche

RIVM (Rijksinstituut Voor Volksgezondheid en Milieu), 1997b, National Institute of Public Health and Environment Maximum Permissible Concentrations and Negligible Concentrations for Metals Authors T Crommentuijn, D.F Kalf, M D Polder, R Posthumus and E J van de Plassche

Suter, G W , II, ed , 1993, Ecological Risk Assessment, Lewis Publishers Boca Raton, Florida

Suter, G W II, 1990, Uncertainty in environmental risk assessment. *In*· Acting Under Uncertainty Multidisciplinary Conceptions, G M von Furstenberg (ed) Kluwer Academic Publishers, Boston

96

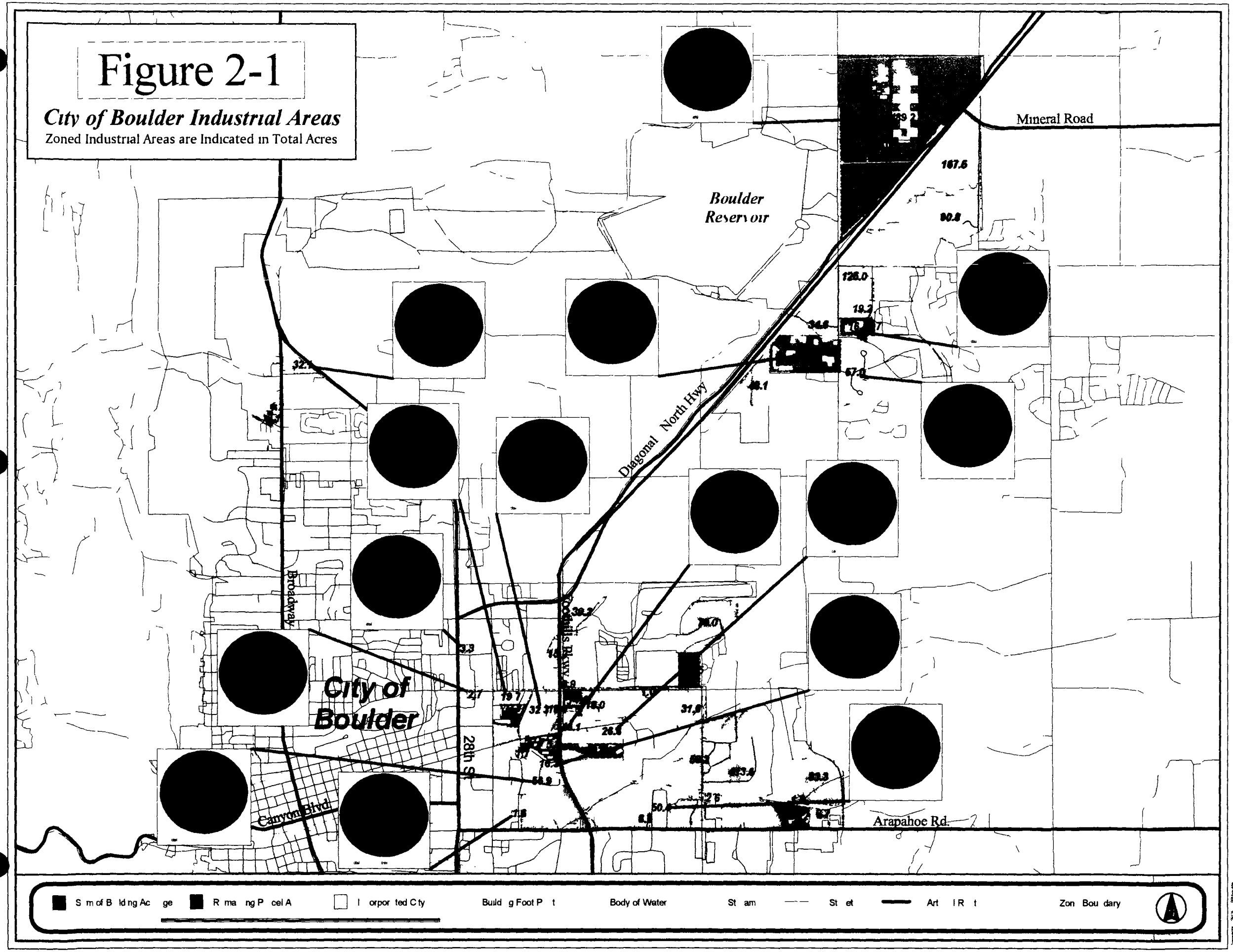
Zeller, M , H Zinn, and M Manfredo, 1993, Boulder County Open Space Visitation Study Colorado State University, Human Dimensions in Natural Resources Unit, Boulder County, Colorado, September

97/97

Figure 2-1

City of Boulder Industrial Areas

Zoned Industrial Areas are Indicated in Total Acres



City of Boulder Industrial Areas

- Industrial General Developing (IG-D)
- Industrial General Established (IG E)
- Industrial Manufacturing Developing (IM D)
- Industrial Manufacturing Established (IM E)
- Industrial Main Street Redevelopment (IMS X)
- Industrial Services Developing (IS D)
- Industrial Services Establisned (IS D)

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Total Acreage of Established Industrial Parcels

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